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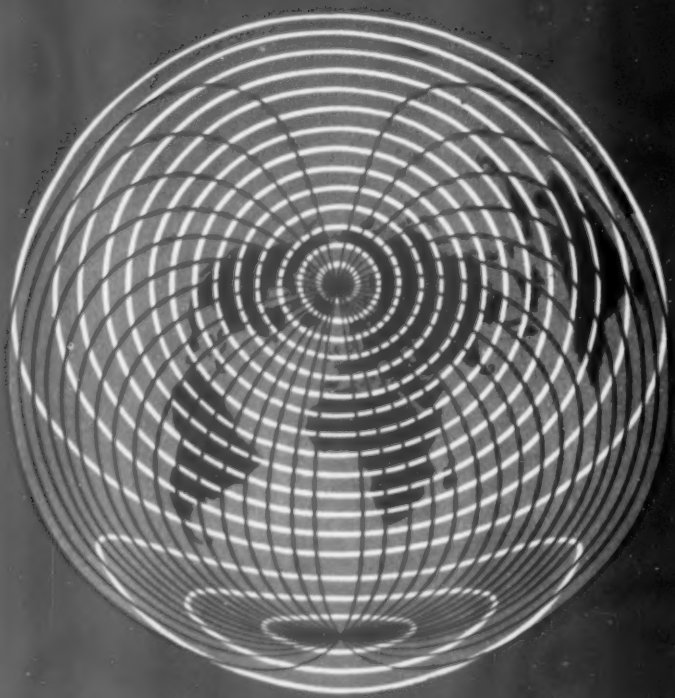

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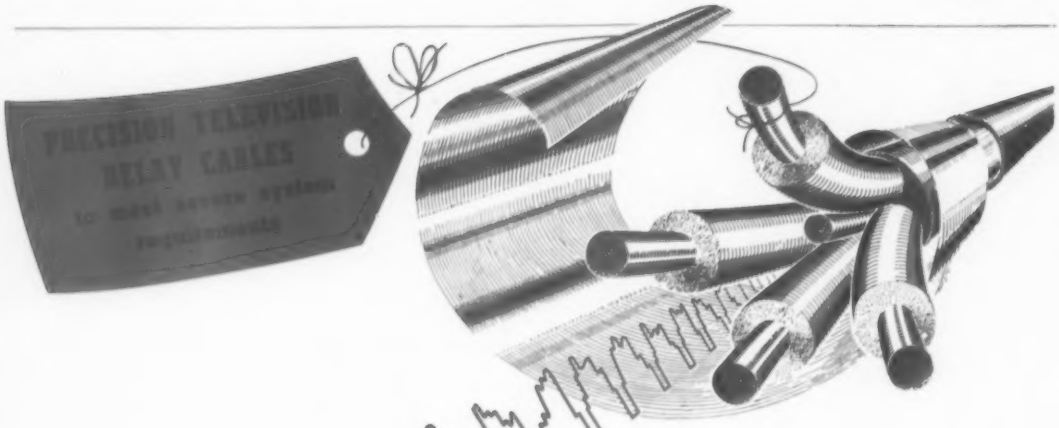

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It is a compact and comprehensive meter that will test quickly any standard receiving valve or small transmitting valve on any of its normal characteristics under conditions corresponding to a wide range of D.C. electrode voltages. The method of measuring mutual conductance ensures that the meter can deal adequately with modern T.V. receiver valves. It does many useful jobs too numerous to mention here, but a completely descriptive pamphlet is available on application.

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oscilloscope mark 2

. . . two input signals displayed for direct comparison and their characteristics accurately measured by the turn of a knob . . . such are the facilities and convenience afforded by the Mullard Dual Trace Oscilloscope, type L.101.

Well-engineered and reliable, the L.101 Oscilloscope is *the* oscilloscope where the demand is for a high grade general purpose instrument. It employs two identical amplifiers with bandwidths of 4 Mc/s irrespective of sensitivity. Each amplifier is aligned for good transient response, has a rise time of 0.1 μsec, and a maximum sensitivity of 20 mV pk-pk/cm.

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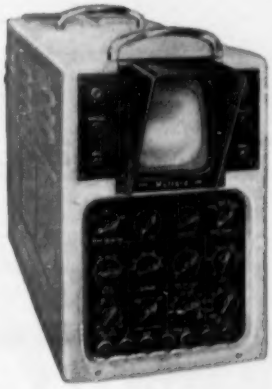

mark 2 features

- **Post Deflection Acceleration** gives a brighter display at low repetition rates.
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Full details of the L.101 Mark 2 are readily available from Mullard at the address below or from any of their distributors.

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Model 66N	Model 66H
3¾" & 7½" p.s.	7½" & 15" p.s.
84 gns	**88 gns**

(including 1,750 ft. Ferrotape on 8¼" reel)

IN great-grandma's time the old oak chest was generally the place where the household linen was stored. But to-day it has another use—at least in the home of Mr. Geoffrey Parnell, of Leeds. He writes: "Wondering how I could house the Ferrograph 66 I had on order, I suddenly noticed an old oak chest which had belonged to my wife's grandmother. It offered the ideal solution because not only did it take the Ferrograph but there was ample room, in addition, for a Garrard turntable and an F.M. Tuner unit".

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Ferrograph "66"

BRITISH FERROGRAPH RECORDER CO. LTD

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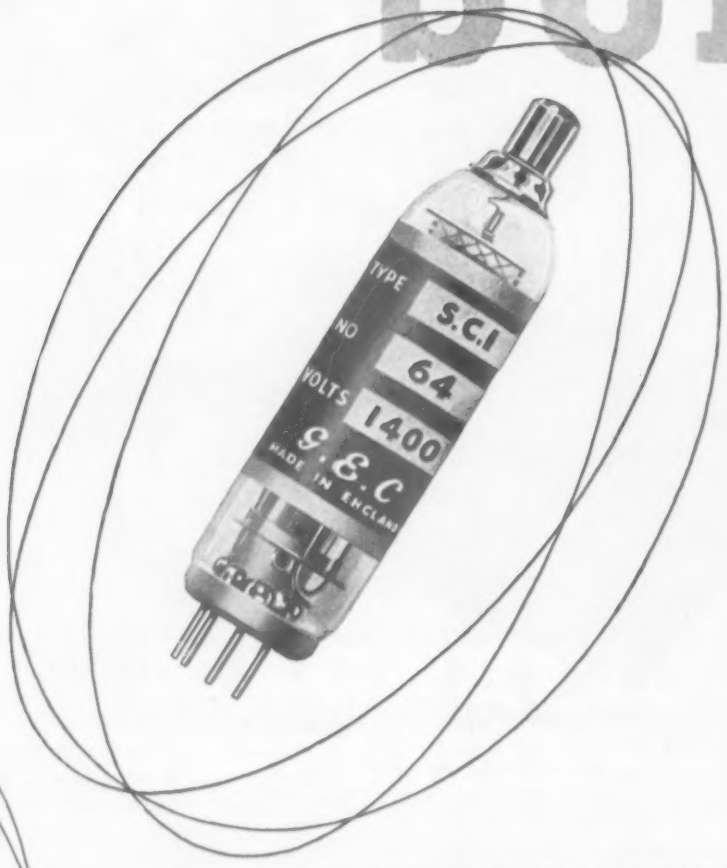
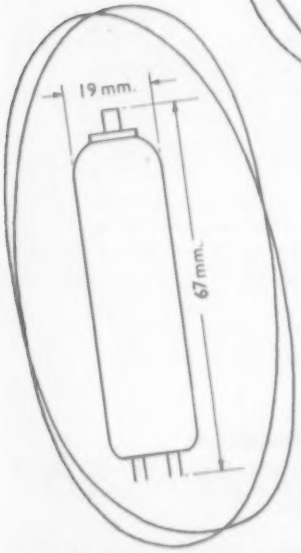
CORONA STABILISER SC1





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These devices are available for providing stable H.T. supplies of 400, 600, 800, 1000, 1200 and 1400 volts. For higher voltages any combination of tubes may be operated in series.

TYPICAL RATING

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Stabilised output	600	1000	V
I tube (max.)	300	300	μA
I tube (min.)	20	20	μA
Tube resistance	50	50	kΩ
Stability	1	1	%

For further information, write to the Valve & Electronics Dept.

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AUDIO PERFECTION

TRANSCRIPTION MOTOR 301

THE GARRARD MODEL 301 TRANSCRIPTION MOTOR

The Garrard Model 301 Transcription Motor is recognised as supreme in its class. With its introduction a hitherto unattainable standard in the manufacture of High Fidelity Gramophone Components has been reached. Features that the enthusiast will appreciate are the suppression of switch clicks, the extra heavy balanced turntable and the very fine degrees of speed control available . . . multi-speed can be adjusted by approximately 2½%.

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The Model 301 is finished in high quality grey tone enamel, is fully tropicalised and is supplied complete with a plastic stroboscope, a tube of special grease, all fixing screws, washers, template and instruction manual. . . . . see your Dealer now.

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Swindon, Wilts, England

50% EXTRA PLAYING TIME with this new tape!

For greater convenience and vastly improved performance, get 'SCOTCH BOY' *Extra Play* magnetic recording tape, No. 150. The new polyester base film is one-third thinner—*and still it is stronger!*—than other bases. That is why a reel carries half as much tape again, and gives you 50% EXTRA PLAYING TIME . . . 1800 feet of tape instead of the usual 1200 on a 7" reel!

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MAGNETIC RECORDING TAPE 150

with polyester base

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Type 761

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- Complete built-in Oscilloscope provided.
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THIS instrument has been designed to fill the need for a versatile, self-contained, crystal-controlled frequency standard of moderate cost. Although relatively small in size a short-term frequency stability of better than 1 part in 10^8 is obtainable upon installation. This short-term stability improves with time and correct treatment up to a limit approaching 1 part in 10^7.

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Pre-amplifier and Main Amplifier
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INPUTS—*Magnetic Pickup*
B.78. 16 mv input for rated output. 300 c/s Turnover. 6 DB Roll-off at 10 Kc/s.
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R.I.A.A. 11.5 mv input for rated output. 500 c/s Turnover. 14 DB Roll-off at 10 Kc/s. 3 DB Flattening at 50 c/s.★
Crystal Pickup. .35 volt with inbuilt equalisation from constant amplitude to constant velocity output enabling switched replaying characteristics to be accurately employed.
Radio/Tape High Level 200 mv. Flat characteristic. Low level 50 mv. Flat characteristic.
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Mixer Facilities for microphone input, with radio/tape gramo inputs.★
OUTPUT. 1.2 volts from cathode follower stage.
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OUTPUT. 12 watts rated. Peak in excess of 20 watts over 25-20,000 c/s.★
DISTORTION. Total harmonic less than .1% at 10 watts—700 cycles.
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Printed Circuit Connectors in high grade black moulded bakelite.
Six, twelve or eighteen way.
Specially designed not to damage printed circuit foil.
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Type 59T.

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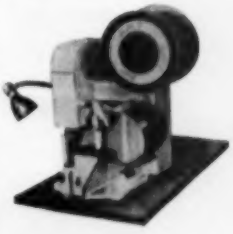

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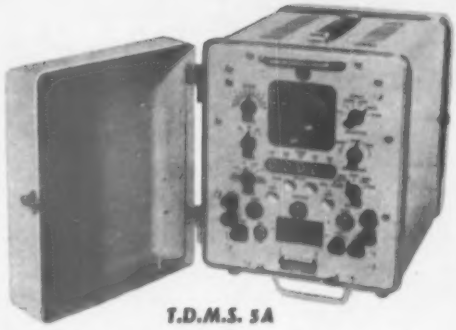

T.D.M.S. 5A

Sends an automatic test message, or characters, or reversals at any speed between 20-80 bands with or without distortion. The CRO has a circular time base for distortion measurements on synchronous signals only, or relay adjustment. Weight 37 lb.

For distortion measurements on working circuits without interrupting service. Each element of a start-stop signal appears separately on the spiral time base display. Adjustable speeds from 20-80 bands. Weight 33 lb. Higher speed versions can be supplied to order.

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SINE AND SQUARE WAVE MODULATION
R.F. OUTPUT 1 μV to 100 mV

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V.H.F. SIGNAL GENERATOR

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This " Advance" V.H.F. Signal Generator covers 7.5 to 250 Mc/s, a range that embraces Bands 1 and 2 *and also the impending Very High Frequency Television Transmissions on Band* 3. Moreover, this instrument is available at a price well within the reach of every service man. In the traditional " Advance " manner, this instrument is designed for simple operation and with a versatility that not only fulfils present needs, but anticipates the even more exacting requirements to deal with the television test problems of tomorrow.

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- COMPETITIVE PRICE

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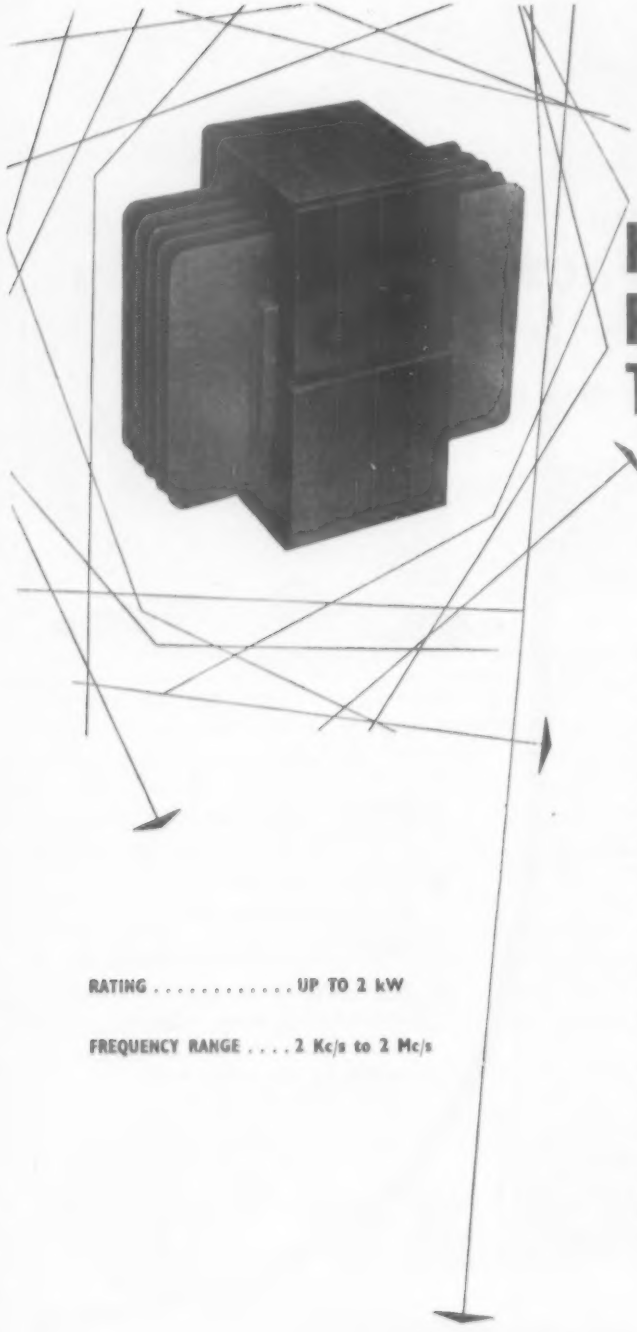

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FREQUENCY RANGE . . . . **2 Kc/s to 2 Mc/s**

H.F. power transformers of outstanding efficiency are the latest additions to the Mullard range of high quality components designed around Ferroxcube magnetic cores.

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Magnadur ceramic magnets
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T	½	250	10 to 10M	240	720
R	1	500	10 to 10M	180	500
Tolerances available ±20% 10% 5%					
HIGH STABILITY RESISTORS					
HS3	½	750	1 to 500M	93	500
Tolerances available ±5% 2% 1%					
WIREWOUND RESISTORS					
LM	5 & 10	—	5 to 100K	72	300
LP	5 & 10	—	5 to 100K	72	300
CERAMICAPS					
CER	Tubular	500	3 to 470pf	141	500
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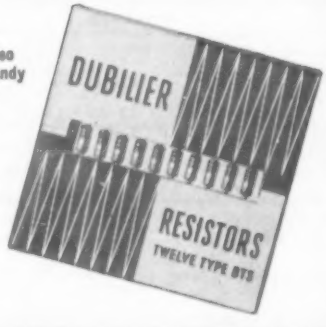
Type BT insulated resistors are completely protected by a phenolic resin housing which is sealed at the ends. Type BTS is rated at ½ watt and Type BTB at 1 watt at 70° C. Resistance range is 100Ω to 10MΩ (BTS) and 390Ω to 22MΩ (BTB).

Type BTS resistors are also available in attractive handy cartons of twelve. These cartons protect the resistors from dirt and permit easy storage and selection in the laboratory or workshop. Save time and trouble by ordering all your ½ watt resistors in the handy carton.



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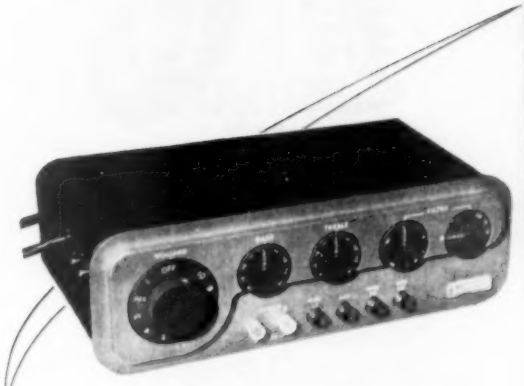
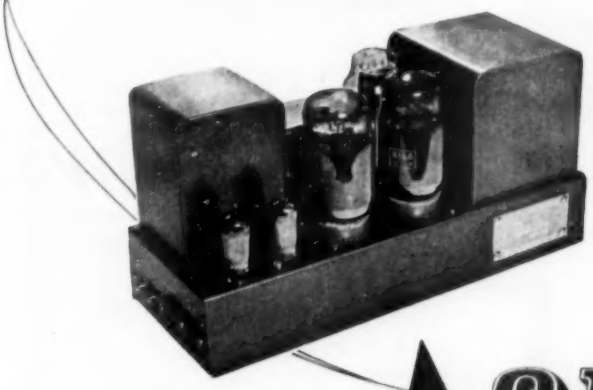
DN 1598

for the closest approach to the original sound





QUAD II

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The criterion, as always, is that the reproduced sound shall be the closest approach to the original — that the enjoyment and appreciation of music may be unimpeded. This is reflected throughout the design of the QUAD II. It is reflected, too, in the straightforward and logical system of control, achieved without the sacrifice of a single refinement or adjustment capable of contributing to the final objective.

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9 WAY

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Covers can be supplied for either plugs or sockets or both in all these types.

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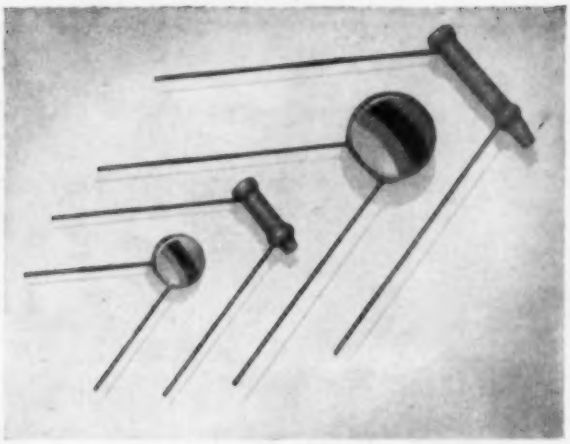
New! Tubular and Disc Ceramics



Hunts announce their new ranges of Tubular and Disc Ceramics. Precise in their characteristics and robust in design, these capacitors are available in High-K, High-Q and Special Purpose Tubulars and in High-K Discs. Full technical specifications on request.

HIGH-Q TUBULAR
STANDARD CAPACITANCE RANGES

Capacitance Range Picofarads	Length of Insulated Tube Millimetres
*Type P100. Temperature Coefficient (+100 ± 100) × 10^{-6} pF/pF/°C	
1.5 to 7	11
7.1 to 11	13
11.1 to 16	16
16.1 to 26	21
26.1 to 33	26
33.1 to 40	31
40.1 to 50	36
50.1 to 60	41
*Type N33. Temperature Coefficient (−33 ± 60) × 10^{-6} pF/pF/°C	
5.0 to 27	11
27.1 to 45	13
45.1 to 69	16
69.1 to 100	21
100.1 to 140	26
140.1 to 180	31
180.1 to 220	36
220.1 to 250	41
*Type N750. Temperature Coefficient (−750 ± 250) × 10^{-6} pF/pF/°C	
10.0 to 80	11
80.1 to 110	13
110.1 to 180	16
180.1 to 240	21
240.1 to 350	26
350.1 to 450	31
450.1 to 550	36
550.1 to 650	41

*Capacitors with closer limits of Temperature Coefficient can be supplied by special arrangement.

HIGH-K TUBULAR
STANDARD CAPACITANCE RANGE

Capacitance Picofarads	Length of Insulated Tube Millimetres	
	TB1000	TB3000
470	11	—
680	11	—
800	11	11
1000	13	11
1500	16	11
2000	19	11
2200	19	11
3000	—	16
3300	—	16
4000	—	19
4700	—	19
5000	—	21

POWER CERAMICS

Ranges of Power Ceramics and Temperature Compensating types are also available.
Details on application.

HIGH-K DISC
STANDARD CAPACITANCE RANGE

Capacitance Picofarads	Type Number	Diameter (over insulation) Millimetres
470	CD8K/2	9
680	CD8K/2	9
1000	CD9K/2	10.5
1500	CD9K/2	10.5
2200	CD11K/2	12
3300	CD12K/2	13
4700	CD14K/2	14.5

MATERIAL EMPLOYED

The temperature coefficient graph of the material is such that the capacitance increases with temperature from 20°C until it reaches a peak at approximately 50°C. With a further increase of temperature the capacitance falls, reaching its 20°C value again at approximately 80°C.
Maintenance of capacitance is thus ensured from 20°C to 80°C.

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new '428' type valve voltmeter is available!

THE MARCONI VALVE VOLTMETER

Type TF 428C

Measures both a.c. and d.c. potentials

The TF 428C first introduced in the 1956 Marconi Instruments catalogue and now available from stock, is the latest of the famous "428" series of valve voltmeters. It has all the well-known "428" advantages in an improved form.

The new cylindrical a.c. probe unit is only ¾" in diameter. It is easy and convenient in use and has a flat response up to 150 Mc/s. A four-valve bridge circuit gives the instrument a really stable "zero" which is not affected by changes in the setting of the range selector. Robustness and compactness are important features of the new design. Light-alloy castings frame the front and rear panels of the welded steel case and the base of the instrument occupies a bench space only 8½" x 9".

ABRIDGED SPECIFICATION

A.C. MEASUREMENTS. Range: 0·1 to 150 volts in five ranges. *Accuracy:* ±2% of f.s.d. ±0·02 volt. *Frequency Characteristic:* 0·2 dB from 100 c/s to 100 Mc/s, 1 dB from 20 c/s to 150 Mc/s. *Input Conditions:* 1 MΩ at 1 Mc/s with 6·5 $\mu\mu$F in shunt. *D.C. MEASUREMENTS. Range:* 0·04 to 300 volts in five ranges. *Accuracy:* ±3% of f.s.d. *Input Resistance:* 50 MΩ.

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The 20A3 is a miniature indirectly heated tetrode thyratron which can be used as a high speed relay. It has a high control ratio, low grid/anode capacitance and passes a very low grid current. Used in conjuction with a high resistance circuit, the 20A3 can be operated directly from a high-vacuum photo-cell.

RATING

Heater Voltage	6.3 volts
Heater Current	0.6 amps.
Arc Voltage Drop	8 volts
Max. Forward Anode Voltage	650 volts
Maximum Peak Invoice Anode Voltage	1300 volts
Max. Shield Grid Voltage	−100 volts
Max. Control Grid Voltage	−100 volts
Max. Peak Cathode Current	500mA
Max. Average Cathode Current	100 mA
Control Grid Circuit Resistance	0.01-10.0 MΩ
Control Ratio G1	250*
,, ,, G2	1000†

BASE B7G MINIATURE

This valve is equivalent to the 2D21

LIST PRICE 15/-

NOTE.—All maximum ratings are absolute values, not design centres. Heater to cathode voltage must never exceed 25 volts peak. The heater must be switched on for a minimum of 10 seconds before the anode voltage is applied.

* *Vg2=0; Rg1=0*

† *Vg1=0; Rg1=0; Rg2=0*

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2½in. scale moving coil D.C. meter, square flush mounting. Type S.25.

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"Fulscale" meter 4in. dia. scale moving coil having 270° arc with a 9in. scale length.

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Universal multi-range test set for electrical and radio engineers.

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Left:
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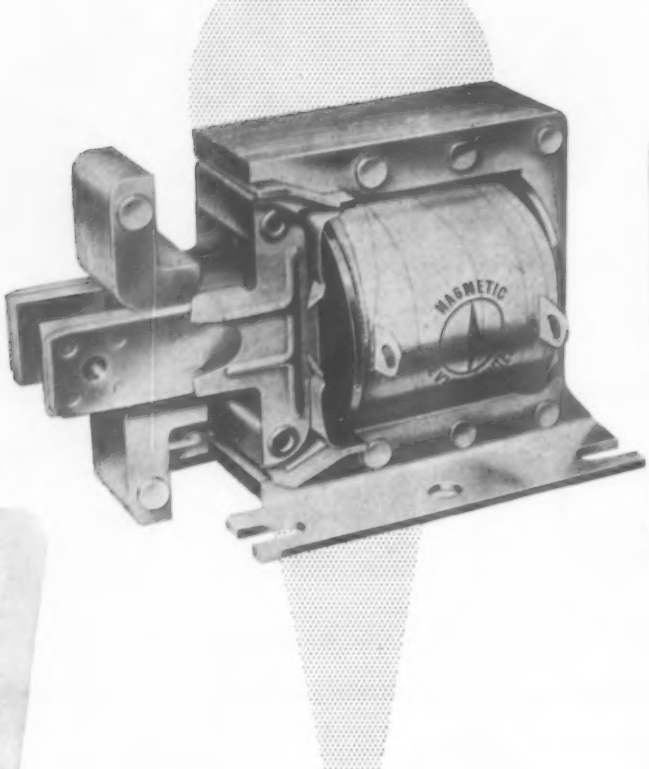

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MD 138

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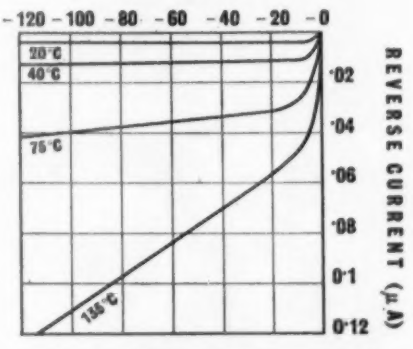
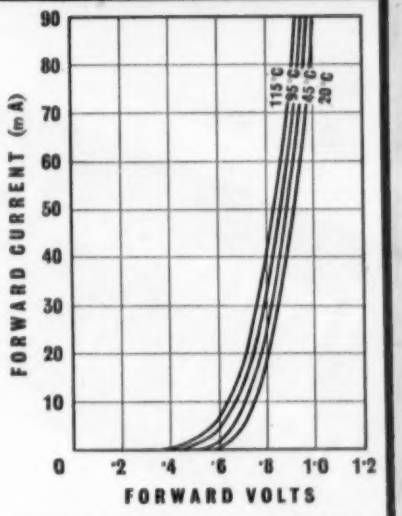
TYPE No.:—		ZS10A.	ZS10B.	ZS20A.	ZS20B.
Max. P.I.V.		60	60	120	120 volts
Max. Voltage for 100mA. Forward Current		1·5	1·5	1·5	1·5 volts
Max. Reverse Current					
for — 50 volts at	25°C	0·05	0·5	—	— μA
	100°C	1·0	5·0	—	— μA
for — 120 volts at	25°C	—	—	0·05	0·5 μA
	100°C	—	—	1·0	5·0 μA
Max. Mean Dissipation at 20° C		150	150	150	150 mW
Max. Operating Temp.		150	150	150	150°C



TYPICAL REVERSE CHARACTERISTICS



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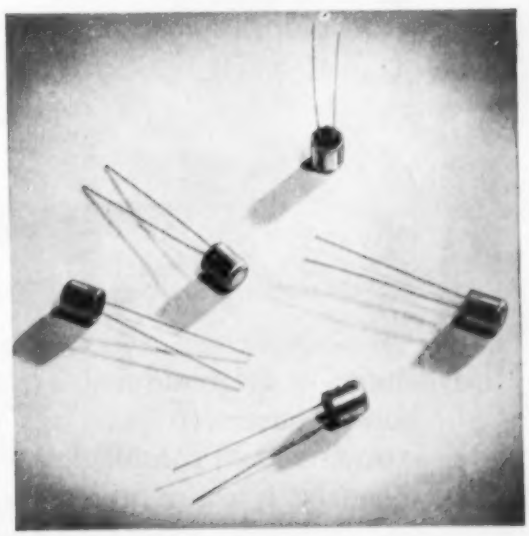

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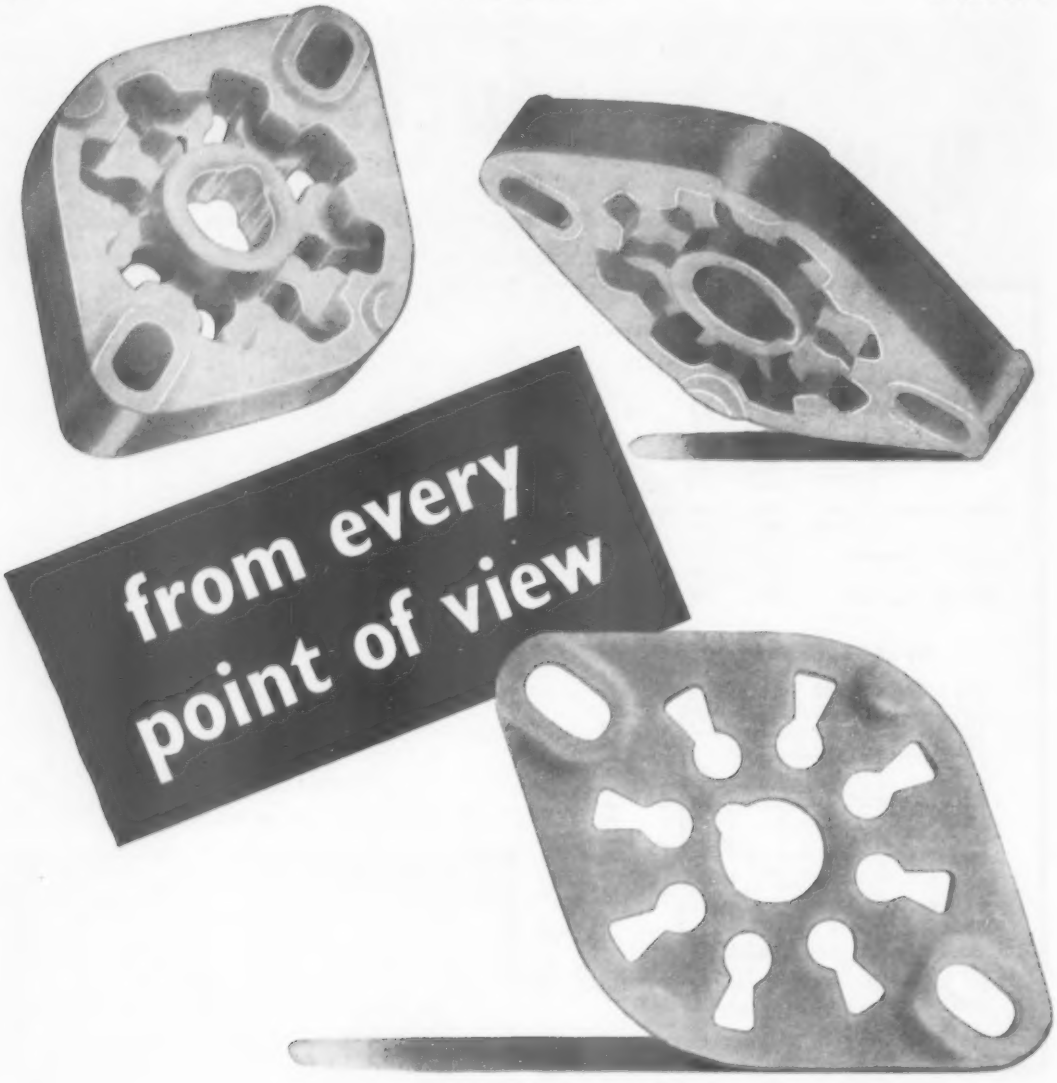

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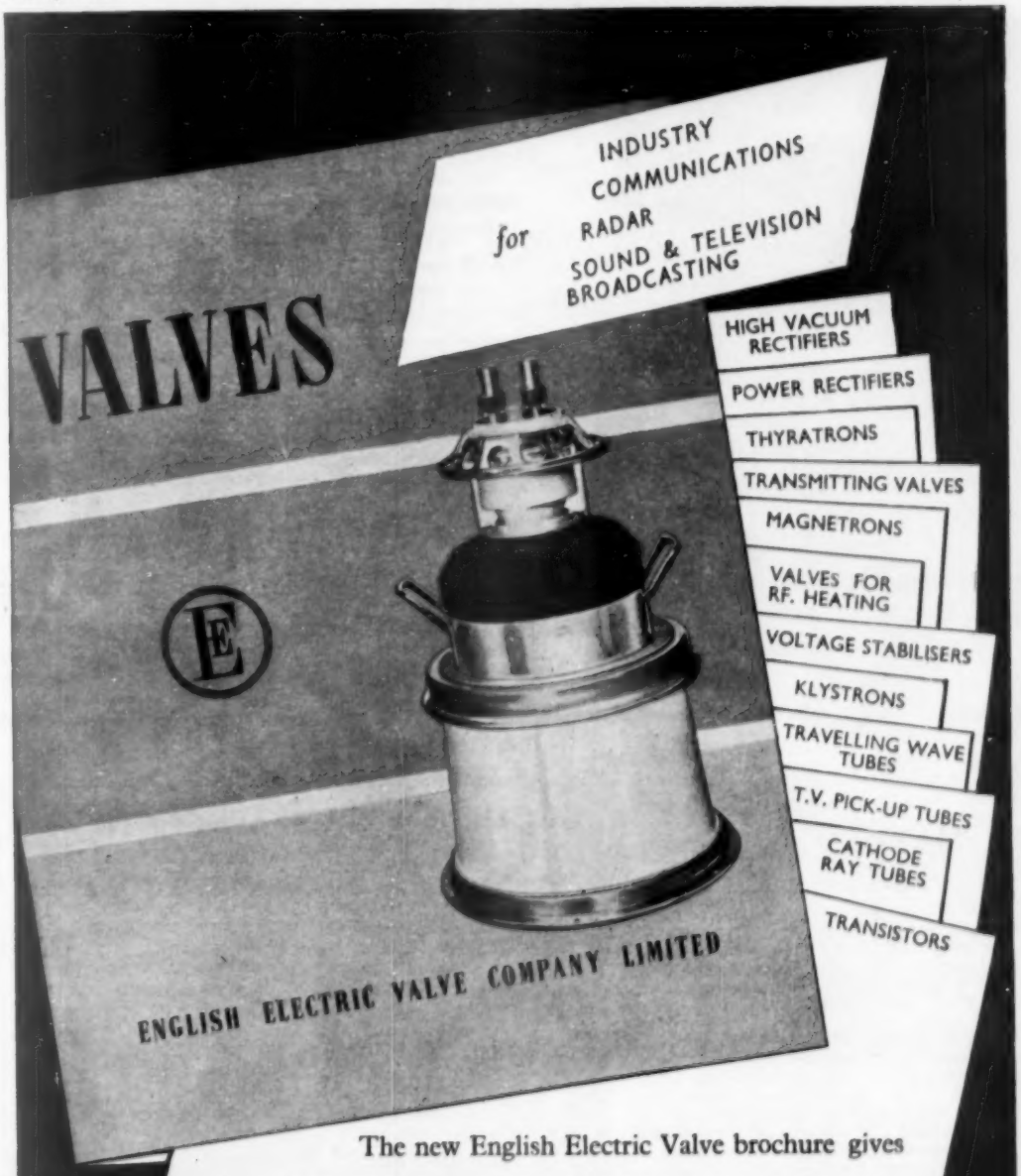

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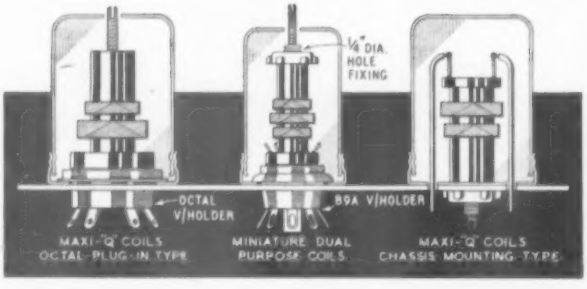

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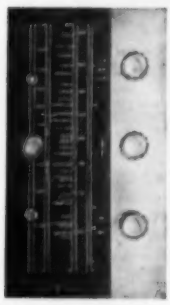
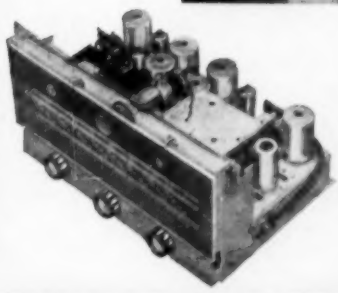
Right The vertical scale model and, *below* the HFT111 in chassis form.





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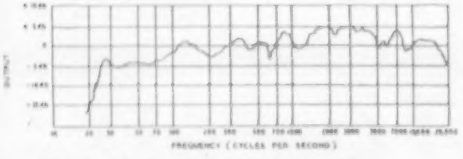
Flux Density	14,000 Gauss
Voice Coil Impedance	4 or 15 ohms. (Please state on order)
Fundamental Resonance	30 c/s
Frequency Coverage	25 c/s-15 Kc/s.
Chassis	Die Cast non-magnetic alloy
Overall diameter	12⅛in.
Overall Depth	6¼in.
Nett weight	7 lbs. 9 ozs.
Packed weight	9 lbs. 9 ozs.



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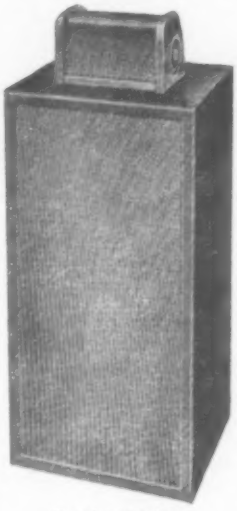
COMPRISING SUPER 3 TWEETER & BRONZE REFLEX

Illustrated on the right is an attractive combination of the new Super 3 Tweeter and the Bronze Reflex Cabinet. This small and compact Two-speaker System gives a well-balanced, wide range response. The total cost, including 10in. Bronze/CSB and Super 3 units, would come to £30 1s. 2d., purchase tax on the two speaker units included, made up as follows:—

Bronze Reflex Cabinet	£14	0	0	
Super 3 Cabinet (10/15 ohms) ...	£3	10	0	inc V.C. & Capacitor
10in. Bronze/CSB	£5	11	3	inc. Tax
Super 3	£6	19	11	,, ,,
	£30	1	2	

Owing to the limited space occupied by this Two-speaker System it is ideal for stereophonic reproduction. The non-directional properties of the Super 3, which has open mounting, also help enormously in obtaining natural results. Construction sheet for Reflex cabinet with acoustic filter free on request.



Size of main cabinet 28" × 14" × 12½"

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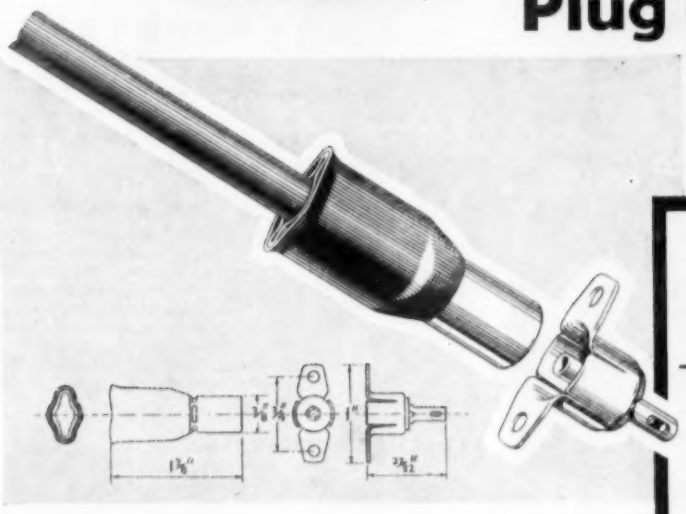
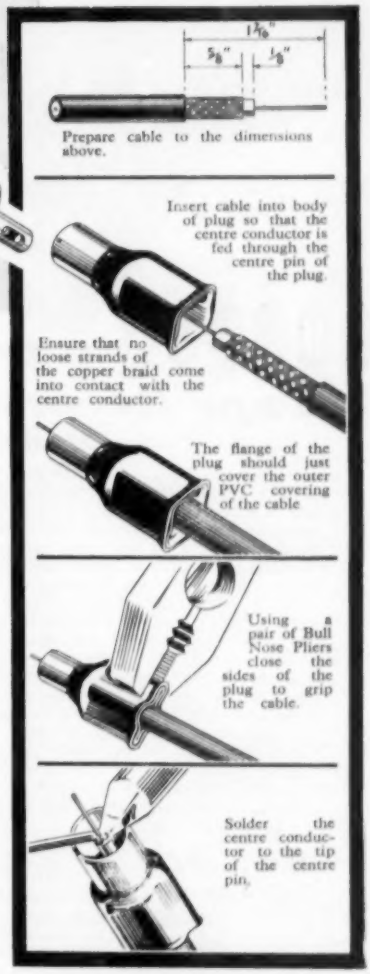
THE ANTIFERENCE STANDARD

Plug & Socket

FOR CO-AXIAL CABLES




1 7/16"
5/8"
1/8"
Prepare cable to the dimensions above.
Insert cable into body of plug so that the centre conductor is fed through the centre pin of the plug.
Ensure that no loose strands of the copper braid come into contact with the centre conductor.
The flange of the plug should just cover the outer PVC covering of the cable
Using a pair of Bull Nose Pliers close the sides of the plug to grip the cable.
Solder the centre conductor to the tip of the centre pin.

The illustrations above show the extremely simple and speedy method of fitting the plug.

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  The Plug is constructed as a "one-piece" unit with no small parts to dismantle.
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  After preparation of the co-axial cable the plug can be fitted in a few seconds.
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- **TROUBLE FREE GRIP**
  Permanent contact is maintained by pressure on the copper braid over a large contact area which holds the cable so that it cannot slip or place any strain on the centre conductor.
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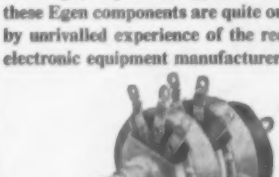

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with concentric operating spindles. Incorporating many outstanding design features, including multiple contact rotors and thorough screening between sections. Control spindles can be supplied to suit customers' requirements. Type 136 less switch. Type 137 with SPST switch. Type 138 with DPST switch.

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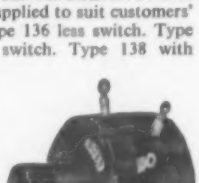

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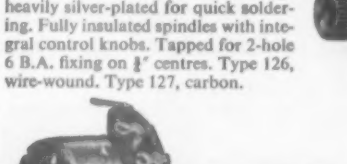

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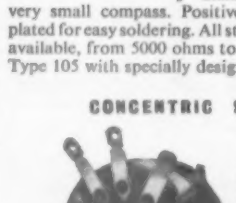

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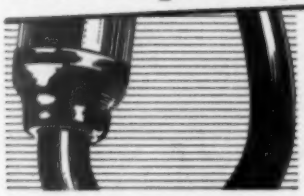

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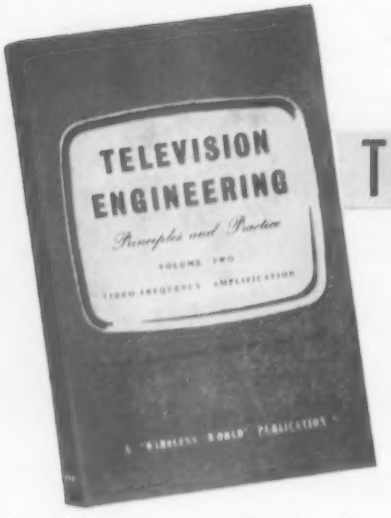

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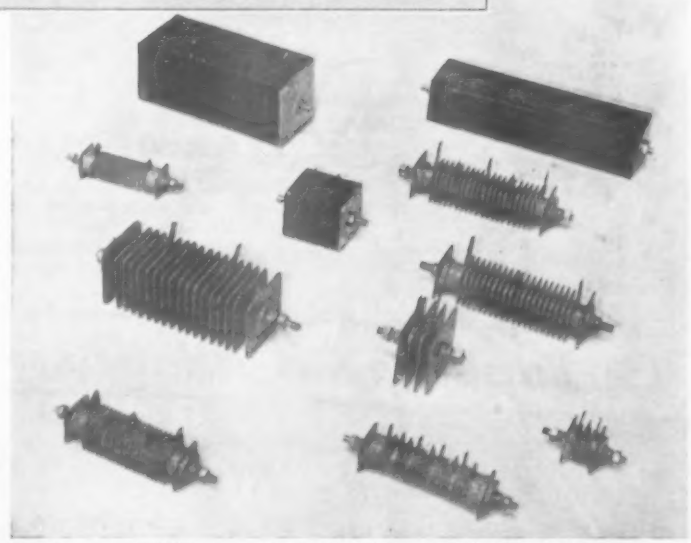

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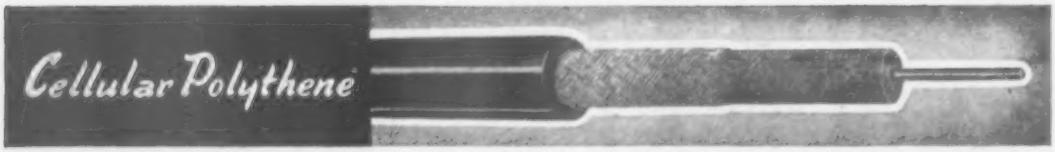

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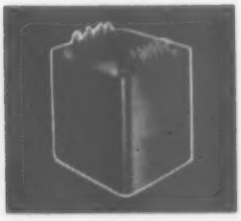

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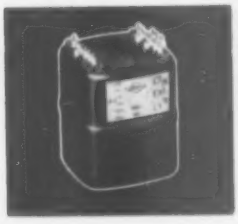

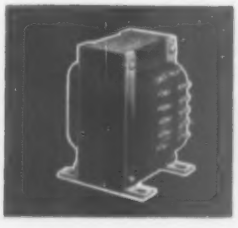

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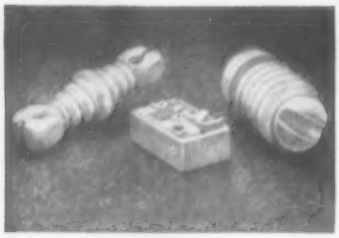

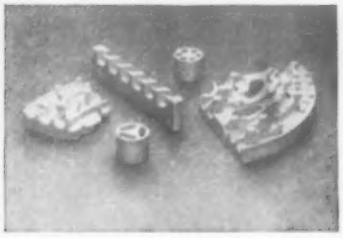

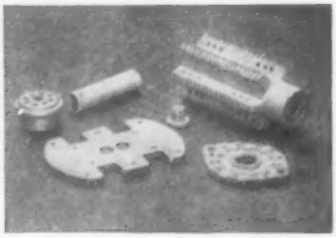

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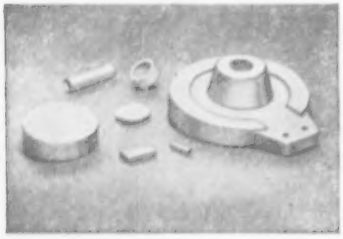

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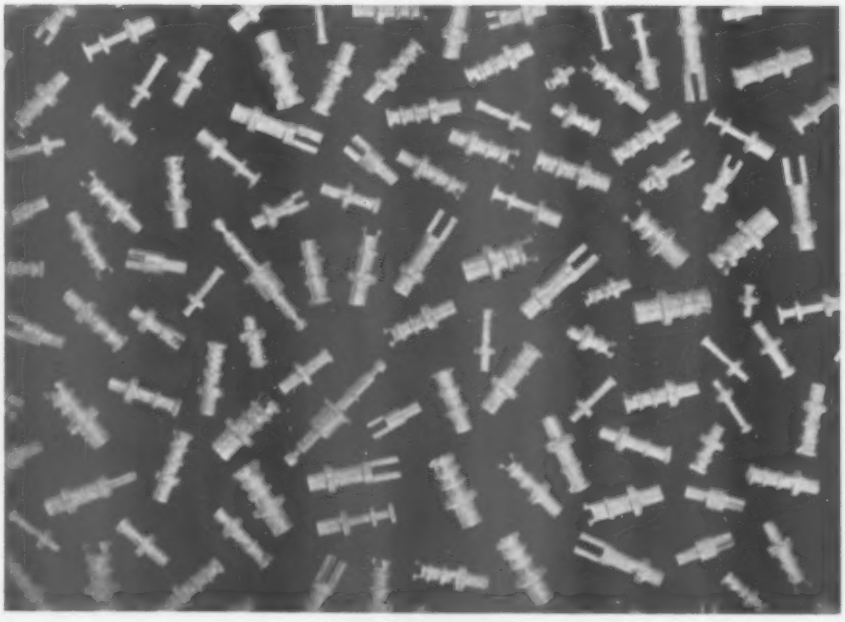

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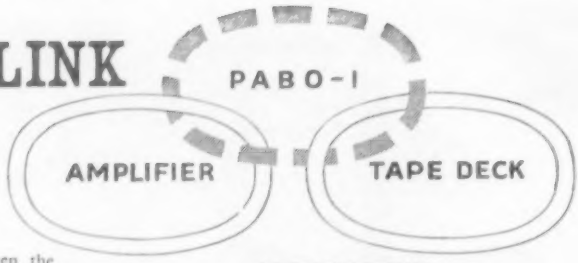
THE MISSING LINK

PABO-1 TAPE PRE-AMPLIFIER AND ERASE UNIT



PRICE : £12.10.0

This compact unit provides the necessary link between the Tape Deck and Amplifier Control Unit in a high fidelity system. The circuit has been critically designed to preserve faithfully the quality of the signal fed to it and to pass it on without distortion or alteration except in so far as the built-in equalising circuits apply. These enable the standard tape recording curve to be applied in recording and the corresponding equalisation on play back. PABO-1 can be used with almost all makes of High Fidelity Amplifier and Tape Deck.

PLAYBACK—One amplifying stage is utilised to increase the tape head signal to the amount required to load the main pre-amplifier to normal working level.

RECORD AND ERASE. The oscillator circuit energises the erase head to clear the tape of all previously recorded material, and supplies the bias voltage for the recording head. A two stage amplifying circuit operates on record.

RECORDING LEVEL. A "magic eye" type valve is used as a recording level indicator, providing an accurate means of setting the correct signal level. The quick rise time and delayed fall away enable transient peaks to be observed for the level to be adjusted accordingly.

SPECIFICATION

CONTROLS: *1. Record/Replay switch. 2. Monitoring volume control. 3. Record level gain control.*

DIMENSIONS: *9in. × 9in. × 4½in. high.*

INPUT REQUIRED: *On Replay—2-3 mV for 100 mV output. On Record—100 mV for full modulation of the tape.*

POWER SUPPLIES: *300 volts at 40 mA; 6.3 volts at 1.2 amps.*

HUM/NOISE LEVEL: *Better than 40 dB down at max. volume.*

BIAS/ERASE FREQUENCY: *60 Kc/s—ensuring negligible intermodulation of Audio, and Erase and Bias frequencies.*

VALVES (Mullard): *EF 86, ECC 83, EL 84, EM 34.*

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Demonstrations at your local High Fidelity specialists or at our showrooms in Holloway. If you are unable to visit us please complete the coupon so that we may send you full descriptive literature.

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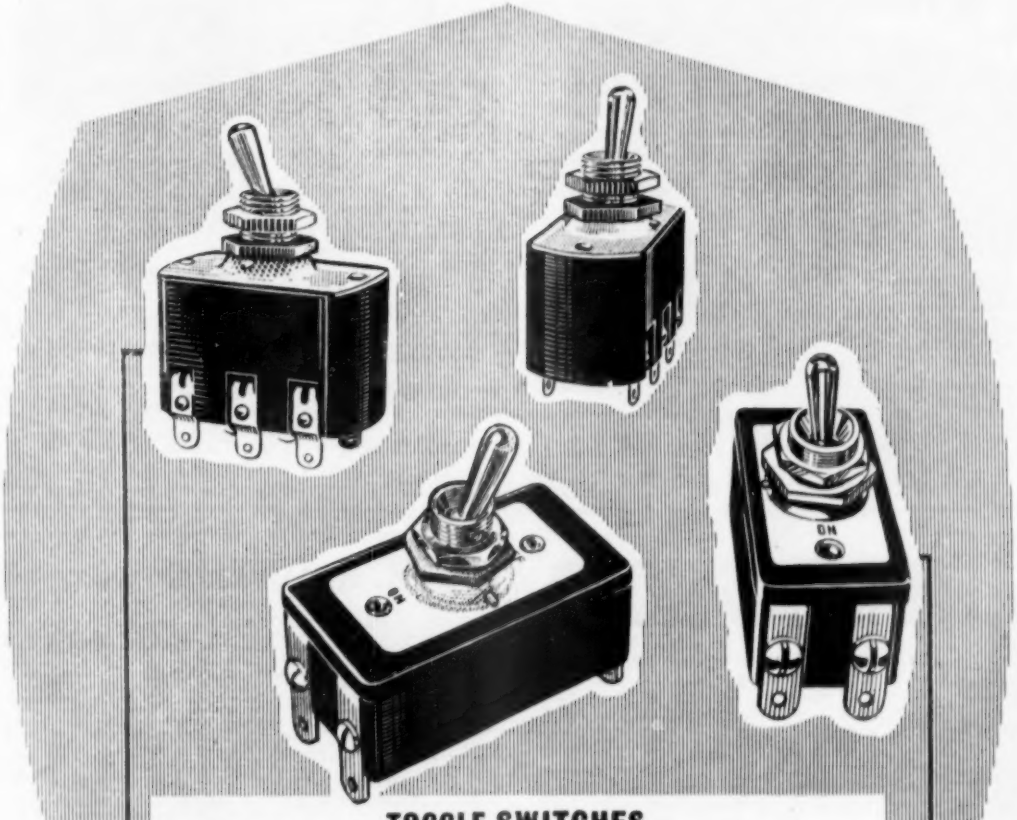

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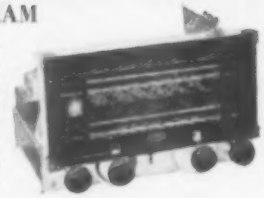

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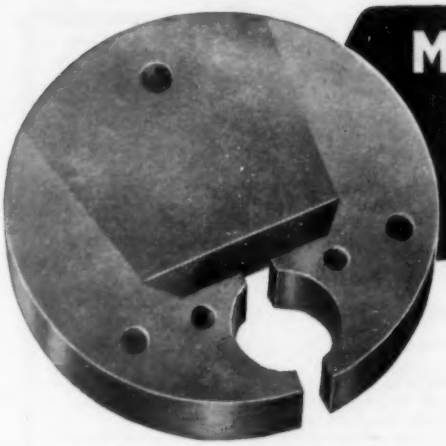

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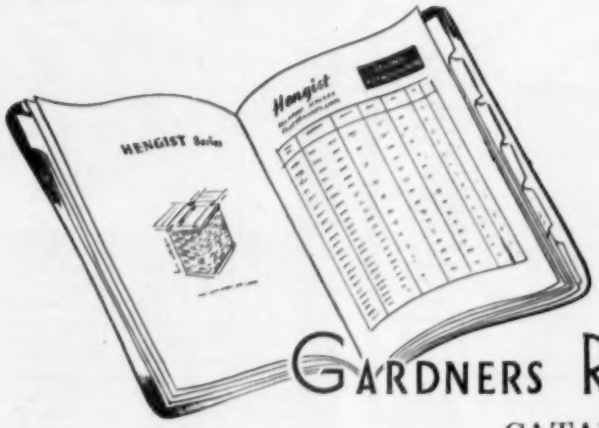

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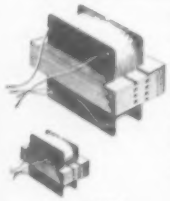

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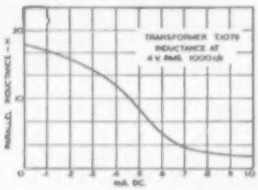

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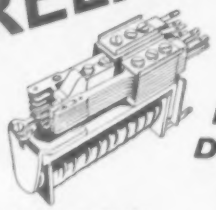

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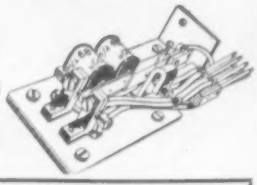

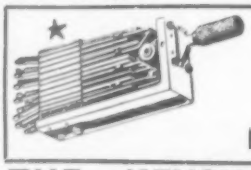

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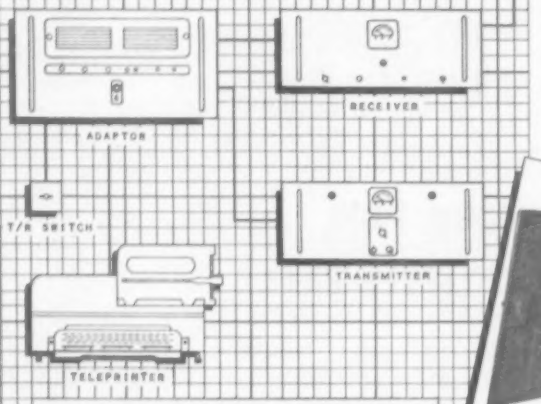

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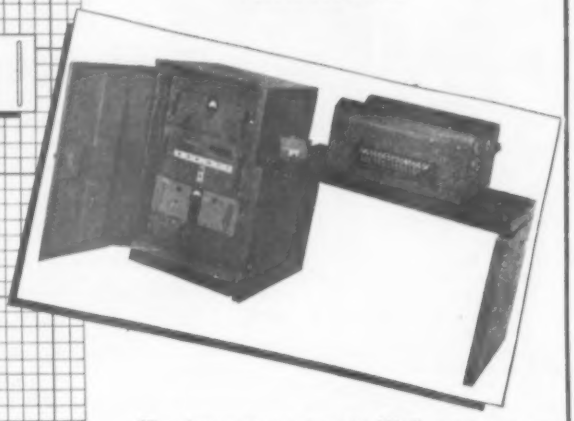

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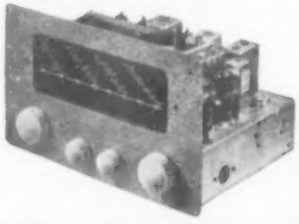

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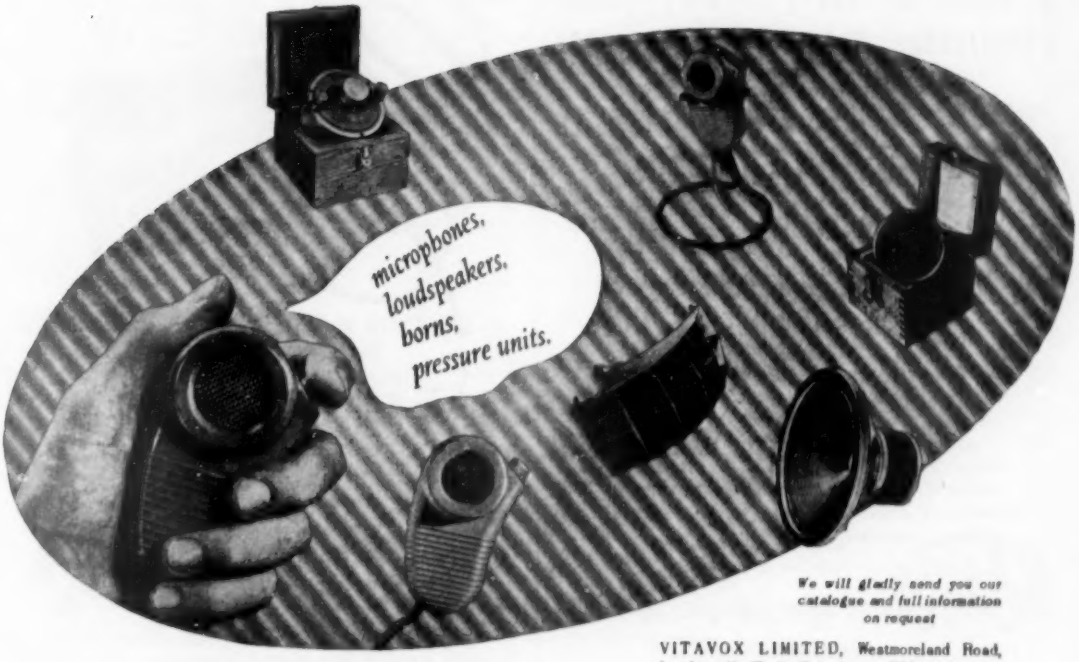

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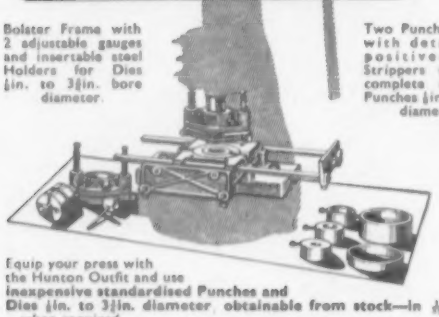

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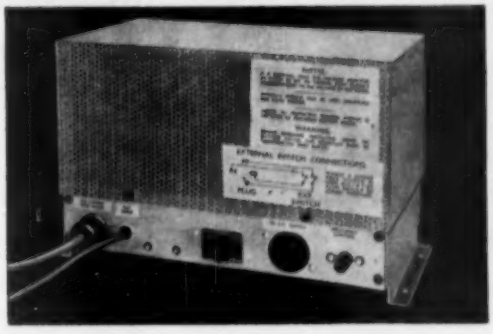

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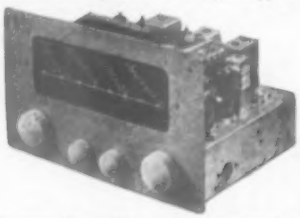

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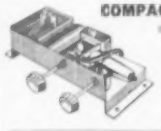

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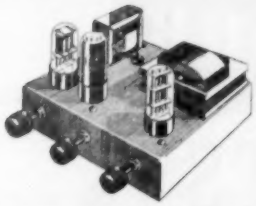

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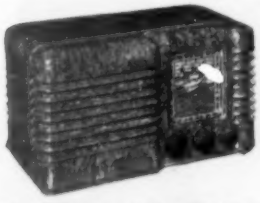

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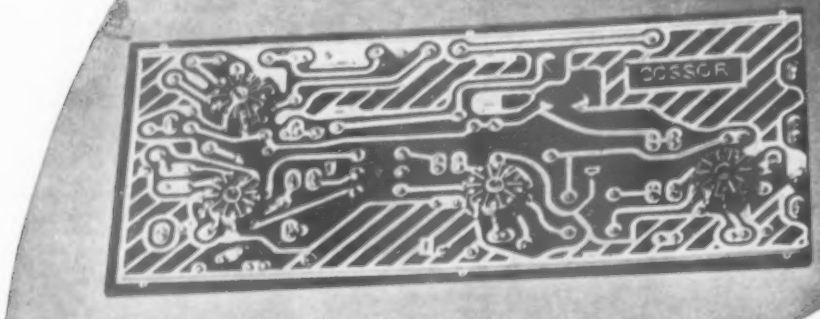

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Wireless World

ELECTRONICS, RADIO, TELEVISION

Managing Editor: HUGH S. POCOCK, M.I.E.E.
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AUGUST 1956

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FORTY-SIXTH YEAR OF PUBLICATION

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Transistors at Small Signals (h-Parameters)

The most convenient way of describing the electrical characteristics of a transistor, like any other electronic device, is by means of a set of static characteristic curves. These graphs show how the voltage or current at the input electrode varies with the voltage or current at the output electrode.

The primary function of transistor static characteristic curves is to enable the circuit designer to choose the direct voltage and current for the working point. In the second place these graphs are used for designing circuits where large signals occur, for example in output stages or pulse amplifiers. However, for applications where the signal is small in comparison with the direct voltages and currents it is possible to calculate performance accurately from the slopes of the characteristic curves at the working point. Under small signal conditions the transistor never moves far away from this point and hence the characteristics in the immediate neighbourhood can be taken as linear. It is generally impracticable to read the slopes with sufficient accuracy from the graphs given, and so they are quoted in transistor data for some nominal working point such as collector voltage —2V and collector current —3mA. The h-parameters are the slopes of a particular set of characteristic curves but are in fact measured by small-signal a.c. methods.

In transistor data, this set of four characteristic curves consists of:—(1) the input characteristic giving the variation of input current I_1 with input voltage V_1, for constant output voltage: slope = h_{11}; (2) the output characteristic showing the relation between the output current I_2 and the output voltage V_2 for a series of fixed input currents: slope = h_{22}; (3) the transfer characteristic giving the variation of output current I_2 with input current I_1 for a fixed output voltage: slope = h_{21}; (4) the feedback characteristic showing the connection between the input voltage V_1 and the output voltage V_2 for a series of fixed input currents: slope = h_{12}.

By drawing the axes of the static characteristic curves and using the subscripts 1 and 2 to refer to the input and output electrodes, the notation h_{11} etc. can easily be explained and three of the h-parameters are seen to be related simply to parameters in the Mullard system. Thus h_{11} is the ratio of two quantities measured at the input electrode, hence it is the slope of the input characteristic, and is equal to r_{in}. V_1, I_1 represent the direct voltage and current at the input electrode and V_2, I_2 similarly apply to the output electrode. The a.c. quantities are v_1, i_1 and v_2, i_2. The formal definition of h-parameters is then as follows:—

$h_{11} = v_1/i_1$ = slope of input characteristic
= input impedance for constant output voltage
= input impedance for output short-circuited to a.c.
= r_{in} (in ohms or kilohms)

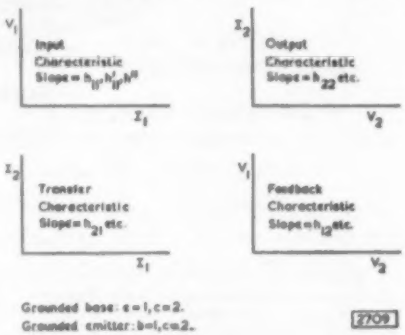
$h_{22} = i_2/v_2$ = slope of output characteristic
= output admittance for constant input current (= reciprocal of output impedance)
= output admittance with input open-circuited to a.c.
= $1/r_{22}$ (usually in micro-mhos)

$h_{21} = i_2/i_1$ = slope of transfer characteristic
= current gain for constant output voltage
= current gain with output short-circuited to a.c.
= α (a ratio, that is, a pure number)

$h_{12} = v_1/v_2$ = slope of feedback characteristic
= voltage feedback ratio for constant input current
= voltage feedback ratio with input open-circuited to a.c.

In defining the h-parameters the transistor is treated as a 'black box' with an input and output, paying no regard to whether the transistor is in a common base, common emitter or common collector configuration. In an actual circuit the values of these slopes will depend on which configuration is used. Thus the undashed terms such as the a.c. current gain h_{21} are reserved for grounded base applications, whereas a single prime as in h'_{21} shows the value required for calculations on grounded emitter circuits, and h''_{21} etc. apply to grounded collector circuits.

Grounded Base	*Grounded Emitter*	*Grounded Collector*
$h_{11} = r_e + (1-\alpha)r_b = r_e + \frac{r_b}{1+\alpha}$	$h_{11}' = (1+\alpha)h_{11}$	$h_{11}'' = h_{11}'$
$-h_{21} = \alpha = \frac{\alpha}{1+\alpha}$	$h_{21}' = \alpha$	$-h_{21}'' = 1+h_{21}'$
$h_{22} = 1/r_c$	$h_{22}' = (1+\alpha)h_{22}$	$h_{22}'' = h_{22}'$
$h_{12} = r_b/r_c$	$h_{12}' = h_{22}'r_e$	$h_{12}'' = \frac{1}{1+h_{12}'}$



Grounded base: c = 1, c = 2.
Grounded emitter: b = 1, c = 2.

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Wireless World

AUGUST
1956

Vol. 62 No. 8

Progress on V.H.F.

DUE to the chaotic conditions prevailing on the medium- and long-wave bands, sound broadcasting on v.h.f. has become a virtual necessity in several European countries. In some of them, large sections of the population are unable to get a tolerable signal, particularly after dark. But, as was stressed in an article which we printed last month, v.h.f. has often been regarded as an "unwelcome complication"; the growth rate has hardly been spectacular.

This applies to some degree in Great Britain, though it would be unreasonable to expect a vast increase in the number of v.h.f. listeners as yet. After all, only some 38 per cent of the population have a service at present. But by the end of the year the figure will have risen to 84 per cent, according to a B.B.C. statement. Can we expect a rapid rise in the number of v.h.f. listeners?

Many of those who stand to benefit from the service have no idea of the advantages to be gained from it. But the knowledge must be spreading, particularly now that the B.B.C. is using its powerful machinery to publicize v.h.f. Then it seems probable that the more attractive receivers which may be expected to make their first appearance at the forthcoming National Radio Exhibition will exert an appeal. There can be no doubt that many of the present sets have their shortcomings. Of these, frequency drift must be one of the most annoying, but in some designs it seems to have been reduced to negligible proportions at no great cost.

Then there is the question of tuning. To us, and no doubt to many of our readers, the right system of channel selection for a three-programme service is by means of a switch or push-buttons. Fiddling with continuous tuning for such a purpose is surely an anachronism. It must be admitted though, that it is not too easy to fit switch tuning into a receiver in which v.h.f. is merely an adjunct to the normal wavebands. That is one of the reasons why we think v.h.f.-only sets should prove attractive to many people, and we hope their number will increase.

Can we learn from the United States anything useful on means of popularizing v.h.f.? In that country the service has for some time been in decline but it now appears to be undergoing a revival. The ever-increasing American interest in high-quality reproduction is apparently responsible, and it seems that the more important surviving stations are concentrating their efforts on programmes of high-class music. According to a report in the American journal *Audio* the listenership for these so-called "music stations" is already large and shortly there will be four of them in New York and six in Boston. But that is not to say the future of v.h.f. in Britain lies in special programmes; conditions are different here and the service must be used mainly to reinforce transmissions on the normal wavebands.

Though the British v.h.f. service cannot be conducted entirely or even mainly for those whose principal interest is in high-quality reproduction of music, their needs should be borne in mind. They are, in a sense, the pioneers of the service and, up to the present, constitute a large proportion of the audience. The B.B.C. has already given assurances that, subject to land-line limitations, the transmissions will permit a substantial improvement in receiver performance, both in frequency range and dynamic range. It should be borne in mind, too, that the quieter background makes all of us—not only the quality enthusiasts—much more critical. In the long run, quality will attract an ever-growing number of listeners.

An interesting proof of the way in which the critical faculty is stimulated by v.h.f. broadcasting has recently come to our notice. When the B.B.C. cut down the frequency range of the Wrotham transmitter, a surprisingly large number of readers observed the falling-off in output and wrote to tell us about it. Here is the explanation of the cut, provided by the B.B.C. engineering department:

"The audio-frequency bandwidth of the transmissions broadcast by B.B.C. v.h.f. stations is, in general, limited by that of the line network connecting the studios with the transmitters in various parts of the country. In the case of broadcasts from local studios a greater range is possible, but it has been found desirable, for the present, to restrict the upper limit to 10 kc/s. Filters have recently been put in at Wrotham to achieve this, and the effect has been observed by keen-eared readers of *Wireless World*. This is a temporary measure, pending the investigation of the causes of a type of distortion that has occasionally been observed in the highest frequency range. It is hoped that the filters will be removed in the fairly near future."

Junction Diode A.F.C. Circuit

A Simple Circuit for Reducing Tuning Drift in F.M. Receivers

By G. G. JOHNSTONE*, B.Sc.

THE junction diodes, such as the Mullard OA10 and G.E.C. SX641 now becoming available are primarily intended for rectification and detection at low frequencies, but in addition they have a property which makes them suitable for entirely different applications.

This property concerns the capacitance between the two electrodes; if a junction diode is biased to non-conduction, the capacitance varies with the applied voltage, being approximately inversely proportional to the square root of this voltage. Thus the diode provides a very compact and simple method of controlling a capacitance by adjustment of a voltage. There are a number of applications for such a facility. An obvious one is the provision of a.f.c. in receivers and this article describes in detail one method of using a junction diode to provide a.f.c. in an f.m. receiver where, in spite of the simplicity of the circuit, it is as effective as a conventional reactance-valve. Another application is the provision of remote tuning for f.m. or other receivers, or the provision of a very fine or "inching" tuning control. It could also be used for f.m. modulation of an oscillator in a transmitter or a wobbulator and no doubt other applications will occur to radio engineers. An effect of this kind is also exhibited by a junction transistor at low frequencies and the amplification of the device could perhaps be used to enhance the effect.

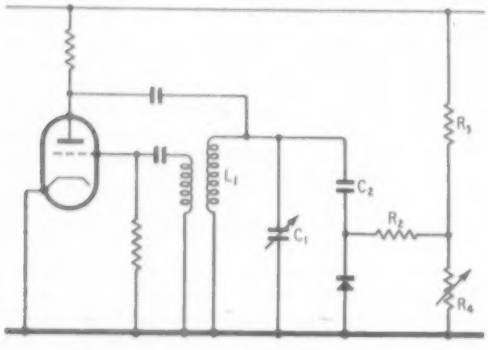


Fig. 1. Circuit used for test purposes.

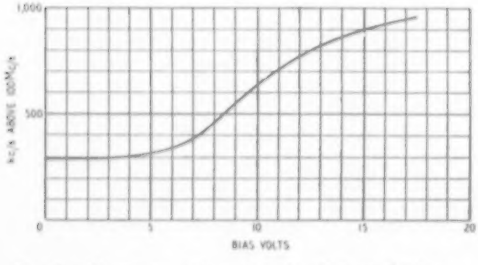


Fig. 2. Frequency shift v. bias for Mullard OA10 germanium diode. Reference frequency 100 Mc/s.

The manufacturers of the OA10 quote the capacitance as less than 30 pF at −0.5 volts bias and less than 10 pF at −3.0 volts bias. These figures apply at low frequencies and it was not expected that they would hold at frequencies as high as 100 Mc/s, such as apply in f.m. receivers. To determine the suitability of the junction diode for providing a.f.c. in such a receiver the circuit shown in Fig. 1 was used. An OA10 is in effect connected directly across the frequency-determining circuit L_1C_1, the 50-pF capacitor C_2 being included to permit application of bias to the diode. The resistor R_2 was included to simulate the internal impedance of the source of control voltage in an a.f.c. circuit, but in addition it prevents undue shunting of the oscillatory circuit and it also behaves as a diode load when the oscillator output voltage exceeds the bias; this has an effect on the shape of the characteristic obtained and is discussed later. The bias voltage is obtained from the potential divider R_3R_4 connected across the h.t. supply and can be varied by adjustment of R_4. To apply the bias in the correct sense to the diode, the diode lead marked in red (which corresponds to the cathode in a thermionic diode) is connected to the positive terminal of the bias voltage.

By varying R_4 and measuring the oscillation frequency the curve shown in Fig. 2 was obtained; at the centre of the characteristic the curve has a region of maximum slope of approximately 100 kc/s per volt, which is of the order of magnitude of control obtained with a conventional reactance-valve circuit. The curvature of the characteristic for low control voltages is due to conduction of the diode, the rectified voltage developed by the diode across R_2 opposing the bias voltage and therefore reducing the change in capacitance. The diode damps the oscillator and in the particular experiment the oscillator output fell from 8.5 volts to 6.0 volts peak value when the diode was connected. This particular characteristic was obtained with a germanium junction diode OA10, but the experiment has been repeated with silicon junction diodes type SX641 which give a curve of substantially the same shape. No doubt other types of junction diodes would also give successful results.

Three silicon diodes were availble for testing and their frequency/bias-voltage characteristics are shown in Fig. 3. They show divergences at low bias voltages where rectification occurs, but are in substantial agreement at other bias voltages. The curves were made to agree with each other at −10

* B.B.C. Engineering Training Department

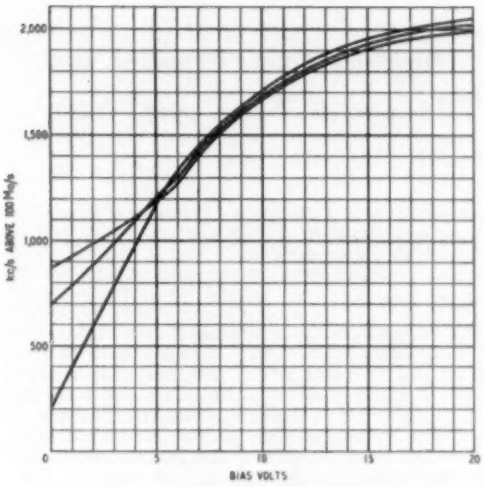


Fig. 3. Frequency shift v. bias for three G.E.C. type SX641 silicon diodes. Reference frequency 100 Mc/s.

volts bias by adjustment of the tuning capacitor C_1. It is not recommended that the region of low bias voltages should be used because there is increased damping of the oscillator circuit and marked divergences of curve shapes.

The experiments showed that the junction diode would operate satisfactorily at 100 Mc/s without undue loss of oscillator amplitude and the next step was to use the diode in an f.m. receiver. The receiver employed is that described in *Wireless World* for May, 1955, and the relevant part of the circuit is reproduced in Fig. 4. It has much in common with Fig. 1, R_{33} and R_{34} being used to provide standing bias for the diode. For most effective a.f.c., and to keep oscillator damping at a minimum, the standing bias should coincide with the centre of the linear portion of the characteristic. This was obtained by making $R_{33} = 100$ kΩ and $R_{34} = 5.6$ kΩ and returning R_{33} to the oscillator h.t. supply point of the feeder unit.

The control voltage is derived from the ratio detector and must be filtered of a.f. signals before application to the junction diode, otherwise negative feedback is obtained and there is a loss of a.f. output. Filtering is achieved by the 470 kΩ series resistor R_{37} and the 0.1-μF shunt capacitor C_{48}. The series resistor forms a potential divider with the diode back resistance causing a reduction in the effectiveness of the circuit and the value of the series resistor must not be made too high for this reason.

A readjustment of the oscillator fixed capacitance is necessary when the a.f.c. circuit is added to the feeder unit because of the standing capacitance of the junction diode. For an OA10 this capacitance is approximately 1.6 pF and can be allowed for by replacing the 8.2-pF capacitor C_9 by a 5-pF component and by advancing the trimmer capacitance C_{13} to restore the original calibration.

The 47-kΩ resistors R_{33} and R_{34} are included to isolate the diode and to prevent oscillator output from entering other parts of the receiver.

When the a.f.c. circuit is added to the receiver it may tend to reduce oscillator tuning errors or to increase them. Three factors determine the behaviour. They are:—

(1), the sense of the discriminator or ratio detector output; (2), whether the oscillator frequency is above or below the signal frequency; and (3), whether the control voltage is applied to the diode anode or cathode.

If the a.f.c. circuit tends initially to increase the tuning error, it may be made to work correctly by alteration of one of the parameters listed above. It is most convenient to apply the control voltage to the diode anode, because this requires the cathode to be returned to a source of positive voltage which can readily be obtained from the h.t. supply. If the control voltage is applied to the diode cathode, the anode must be returned to a negative potential, which is inconvenient to produce; thus alteration of factor (3) is not really practicable. It is inconvenient to alter the oscillator circuit frequency to the other side of the signal frequency because this may upset the frequency coverage or the ganging of the receiver. If the a.f.c. circuit does tend to increase tuning errors it is best to reverse the connections to the ratio detector diodes and the associated electrolytic capacitors to put matters right.

The circuit illustrated gives a reduction in mistuning of approximately 3 : 1. Tuning the receiver with the a.f.c. system operative is somewhat disconcerting because signals appear to have a large spread, and the error-reduction makes the location of the correct tuning point difficult. It may be desirable, therefore, to include a means of removing the a.f.c. whilst tuning the unit. This may be done by the inclusion of a single-pole switch across C_{48} as shown dotted in Fig. 4. A non-locking type is preferable for this application to ensure that the a.f.c. is not permanently defeated!

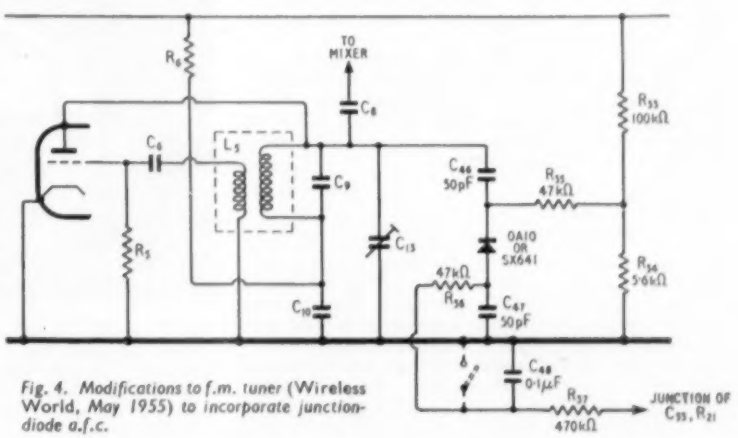


Fig. 4. Modifications to f.m. tuner (Wireless World, May 1955) to incorporate junction-diode a.f.c.

WORLD OF WIRELESS

Organizational, Personal and Industrial Notes and News

Marine V.H.F.

WRITING in *Wireless World* last October on the subject of the P.M.G.'s announcement that f.m. is being adopted by the U.K. for marine v.h.f., R. I. T. Falkner, of Pye Marine (champions of a.m.), said, "If the new P.M.G. can restore confidence and show sincerity by positive action we would be the first to support him." It is interesting, therefore, to note that Pye have, in fact, secured the contract for supplying and installing the first frequency-modulated v.h.f. coastal radio-telephone station to be set up by the G.P.O.

The station, which will be located south of Rothesay, on the Isle of Bute in the Firth of Clyde, will open in the autumn and will provide radio-telephone communication between telephone subscribers in this country and suitably equipped ships operating within a radius of up to thirty-five miles of the station.

The station will operate on the frequencies tentatively agreed for "marine v.h.f. public correspondence"—157.4 Mc/s (receive) and 161.9 Mc/s (transmit). It is hoped that these and the other frequencies recommended at the Gothenburg Conference (*see W.W.*, April, 1956) will be approved at the next international conference.

It was stated by Mr. Falkner that in consequence of the adoption of f.m. the a.m. station on Shooters Hill, London, for the Thames Radio Service would eventually be scrapped.

Amateur Recording Contest

IT is hoped that this year a greater number of British entries will be received for the Concours International du Meilleur Enregistrement Sonore (C.I.M.E.S.) which is organized by the leading amateur recording associations of the world to find the best examples of recording technique as applied to a variety of subjects. Valuable prizes are offered, and in past years many of the entries have subsequently been broadcast.

Copies of the rules and entry forms (English version) are in the hands of the British Sound Recording Association and can be obtained from H. J. Houlgate, 12, Strongbow Road, London, S.E.9 on receipt of a stamped addressed envelope. The closing date is September 15th.

I.E.C. Meeting

STANDARDIZATION of electronic equipment and components was one of the many subjects discussed at the 21st general meeting of the International Electrotechnical Commission. The meeting, held at Munich from June 26th to July 6th, was attended by a number of British delegates representing industrial firms, trade and research organizations and Government departments. In this country the British Standards Institution is responsible for participation in the work of the I.E.C., which is a non-government association of electrical manufacturing and power-producing and consuming industries of 33 countries.

Valve Prices

THE British Radio Valve Manufacturers' Association (B.V.A.) announced on July 2nd reductions of from 10 to 33% in valve prices—the first change since 1950. Reductions of from 14 to 17½% are also made in c.r.t. prices. It is, however, stressed by the B.V.A. that these reductions apply only to current makes of valves and tubes bought by the general public and will not necessarily affect the cost of receivers.

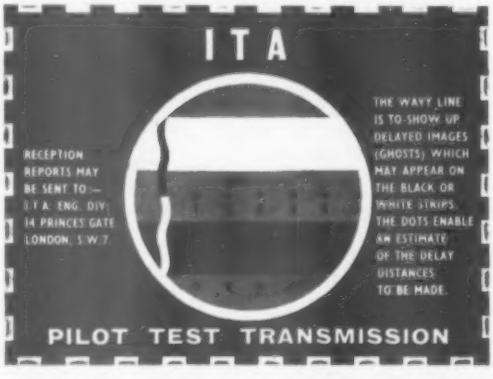
The vice-chairman of the Association, G. A. Marriott, has stated that the reductions have not been introduced because the Monopolies and Restrictive Practices Commission is investigating the supply of valves but because of economies resulting from extensive capital expenditure on plant. These economies, incidentally, will not affect the cost of production of obsolescent valves, the prices of which may even have to be increased.

We learn from manufacturers who are not members of B.V.A. that their prices have been similarly reduced.

"*Transistorized*" *Car Radio*

BY USING transistors in the output stage and for the generation of h.t. for the preceding valves, the drain on the car battery has been considerably reduced in the new Pye TCR16 car radio receiver.

The transistors are new power types (Pye V30/20P), and two in push-pull give an output of four watts. A third (V30/10P) is used as a high-frequency relaxation oscillator, the output of which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THE WAVY LINE IS TO SHOW UP DELAYED IMAGES (GHOSTS) WHICH MAY APPEAR ON THE BLACK OR WHITE STRIPS. THE DOTS ENABLE AN ESTIMATE OF THE DELAY DISTANCES TO BE MADE.
PILOT TEST TRANSMISSION

TEST CARD now being transmitted from the site of I.T.A. station on Emley Moor, Yorks., due to open in the late autumn. The card helps in locating sources of reflection causing "ghosting". Times of test transmissions are: Monday-Friday: 10 a.m.-12.30 p.m., 2-5.30 p.m., 6-7 p.m. Saturdays: 10 a.m.-12.30 p.m.

is stepped up in a ferrite-cored transformer to give, after rectification and smoothing, 10mA at 100 V.

A frequency changer valve (12BE6) is followed by a single i.f. stage (12BA6), germanium diode detector and a triode-pentode (PCL83) first a.f. amplifier and driver for the Class B output transistors. To assist in achieving thermal stability a thermistor is included in the transistor base circuit.

I.L.S.-S.B.A. Decision

ALTHOUGH the standard pilot-interpreted approach aid in Europe is I.L.S. (instrument landing system), there are a number of aerodromes in the United Kingdom still equipped with S.B.A. (standard beam approach). This is obviously undesirable as it may entail an operator having to carry two sets of airborne equipment. The Ministry of Transport and Civil Aviation is, therefore, withdrawing S.B.A. from its civil aerodromes as soon as this can be done without causing undue inconvenience to those operators who use it.

S.B.A. is, however, being retained at some of the aerodromes not directly the responsibility of the M.T.C.A., as for instance on the Isle of Man where it is stated it "will not be withdrawn until the aid is no longer fitted in the majority of the smaller aircraft."

PERSONALITIES

Sir George H. Nelson, Bt., has relinquished the position of managing director of the English Electric Company in order to devote the whole of his time to the duties of executive chairman of the company. His son, **H. G. Nelson,** M.A.(Cantab.), M.I.E.E., who has been deputy managing director since 1949, has been appointed managing director. He is 39 and has been a director of the Marconi companies since they joined the English Electric group in 1946. Sir George, who is this year's president of the I.E.E., is a member of the governing body of the Imperial College of Science and Technology.

W. H. Stephens, head of the guided weapons department of the Royal Aircraft Establishment, Farnborough, since 1953, has been appointed deputy director (equipment) of the R.A.E. on the retirement from Government service of Dr. F. E. Jones. Mr. Stephens, who was with the Ministry of Aircraft Production during the war, was for three years a member of the British Scientific Mission in Washington. It will be recalled that his lecture on guided weapons to the Radar Association during the last session formed the basis of an article in our February issue.

E. W. Chivers, B.Sc., has been appointed principal superintendent of the electronics division of the Armament Research and Development Establishment (M.o.S.) at Fort Halstead, Sevenoaks, Kent. Mr. Chivers, who is 49, held a number of Government scientific appointments during the war and was for two years superintendent of the General Physics Committee of the Scientific Advisory Council. He became superintendent at the Radar Research and Development Establishment at Malvern in 1947 and on the fusion in 1953 of R.R.D.E. and T.R.E. into the Radar Research Establishment was appointed deputy director of ground radar. His rank in the Scientific Civil Service is deputy chief scientific officer.

R. E. Burnett, M.A.(Oxon), A.M.I.E.E., A.Inst.P., has succeeded J. M. Furnival, M.B.E., who has retired, as general manager of Marconi Instruments. Mr. Burnett, who joined Marconi's in 1950 as principal of Marconi College and manager of education and technical personnel, was appointed deputy general manager of Marconi Instruments last November.

In order to co-ordinate television engineering development Marconi's have created the post of chief television engineer, to which **V. J. Cooper,** B.Sc., A.C.G.I., M.I.E.E., M.Brit.I.R.E., has been appointed. His deputy is **G. E. Partington,** B.Sc., A.M.I.E.E. For the past eighteen months Mr. Cooper, who has been with the company since 1936, has been chief engineer, advanced development. Mr. Partington joined Marconi's in 1938 when he attended a post-graduate engineering course at the Marconi College. Since 1947 he has been in charge of the development of television studio equipment. Under this scheme of unification Marconi's have formed three television development groups under **E. Davies, N. N. Parker-Smith,** B.Sc., A.M.I.E.E., and **J. E. Nixon,** B.Sc., A.C.G.I., A.M.I.E.E., and an audio development group with **S. J. Gooderham** in charge.

V. J. COOPER

G. E. PARTINGTON

C. G. Mayer, M.I.E.E., has been appointed chairman and managing director of R.C.A. Great Britain, Limited, on the resignation of P. A. Turnor, who will continue to serve as a director and executive of the company. Mr. Mayer, who has been European technical representative of the parent company, Radio Corporation of America, since 1947, was responsible for the recent formation of Laboratories R.C.A., Limited, in Zurich, Switzerland, of which he became president and managing director. He will continue as a consultant to the Laboratories.

Joseph R. Pernice, who has been chief of the electronics section of N.A.T.O.'s production and logistics division for the past six years, has been appointed managing director of Collins Radio Company of England, Limited, the recently formed subsidiary of Collins Radio Company, of Iowa, U.S.A. He took up his new appointment on July 1st and will be responsible for all Collins' operations in Europe.

Brian Cape, Associate I.E.E., has been appointed technical services manager to Kelvin and Hughes (Aviation), Ltd., in succession to John Rivaz who recently joined Smiths Aircraft Instruments, Ltd. After seven years in the R.A.F., where he specialized in airborne radar equipment, Mr. Cape became manager of the radio department of Flight Refuelling, Limited. He joined Kelvin and Hughes in 1947 as a development engineer, working principally on airborne navigation equipment. He is 38.

H. Henderson, B.Sc., A.Inst.P., who, in this issue, contributes an article on the theory of colour, is a senior lecturer in the engineering training department of the B.B.C. where he lectures on this subject during the short colour television courses organized by the Corporation for its senior technical staff. After three years as an experimental officer with the Admiralty Signals Establishment, Witley, he spent six years as physics master at grammar schools in London and Leeds before joining the B.B.C.

NATIONAL RADIO EXHIBITION

(Earls Court, Aug. 22nd—Sept. 1st, 11 a.m.—10 p.m.)

WIRELESS WORLD SHOW NUMBERS

September: Show Guide (publication date August 21st*). Plan of the stands with stand-to-stand guide to the exhibits.

October: Show Review (publication date September 25th). An analysis of design trends in television and sound receivers.

* Note advanced publication date

OBITUARY

E. A. Richards, M.B.E., B.Sc., A.C.G.I., M.I.E.E., formerly chief rectifier engineer of Standard Telephones and Cables, Limited, died on June 20th, aged 71. His engineering career began with Siemens Brothers. In 1929 he joined the European Commercial Department of the International Standard Electric Corporation; was transferred to S.T.C. two years later and from 1934 until 1936 was chief engineer of Broadcast Relay Services. Returning to S.T.C. in 1936, he took charge of the engineering and development groups of the rectifier division, pioneering in the United Kingdom the selenium metal rectifier. It was for his work on increasing the production and improving the manufacture of selenium rectifiers during the war that he was appointed an M.B.E.

IN BRIEF

More than half the 2,617,429 holders of **receiving licences** in the London postal area now operate television receivers—1,315,921. There were 14,293,902 broadcast receiving licences—including 5,863,473 for television and 299,749 for car radio—current in the U.K. at the end of May.

Additional sound and vision transmitting equipment has been installed at the **I.T.A.'s Lichfield station.** Although at present available as a standby in the event of a breakdown, when certain ancillary equipment has been installed early in the autumn it will be utilized to increase the transmitter's e.r.p. from 50 to 200 kW.

Professional Engineers' Pensions.—A scheme to provide continuous pension cover for a professional engineer throughout his career, whatever changes of employment take place, is to be launched in the autumn by the Engineers' Guild (78, Buckingham Gate, London, S.W.1). It will be open to all members of the institutions of electrical, civil and mechanical engineers.

1957 Audio Fair.—It is announced, by the organizing committee of London's first Audio Fair held in April, that the 1957 exhibition will be held at the Waldorf Hotel, London, W.C.2, from April 12th to 15th—immediately following the R.E.C.M.F. Components Show (April 9th to 11th). The scope of the Fair is to be extended—including a day reserved for overseas and trade buyers—but the plan of the show will be unaltered, each exhibitor having at his disposal a demonstration room.

The scope of the Instruments Exhibition, which has been sponsored in previous years by five trade associations (including the British Electrical and Allied Manufacturers' Association and the Scientific Instrument Manufacturers' Association) is being broadened, and the 1957 show will have the title **"Instruments, Electronics and Automation."** It is being promoted by the same five associations, and will be held at Olympia, London, from May 7th to 17th. The organizers are Industrial Exhibitions, Limited, 105-106, New Bond Street, London, W.1.

The theory, preparation, properties and applications of **Ferrites** will be covered at a convention to be held at the Institution of Electrical Engineers, Savoy Place, London, W.C.2, from October 29th to November 2nd. The convention will be open to non-members on payment of a registration fee of £1. Registration forms and further particulars are obtainable from the Institution.

I.E.E. Officers.—Sir Gordon Radley, K.C.B., has been elected president of the I.E.E. for 1956/57 and G. S. C. Lucas, O.B.E., chief electrical engineer of B.T-H., is a vice-president. The new chairman and vice-chairman of the Radio and Telecommunication Section are, respectively, Dr. R. C. G. Williams, B.Sc., chief engineer of Philips and G. Millington, M.A., B.Sc. (Marconi's). New ordinary members of the section committee are W. J. Bray, B.Sc. (Post Office), H. A. M. Clark, B.Sc. (E.M.I.), C. W. Earp, B.A. (S.T.C.) and V. J. Francis, B.Sc., F.Inst.P. (G.E.C.).

"CABMA Register" is published annually for the Canadian Association of British Manufacturers and Agencies whose object is to develop the Canadian market for British goods through the British trade centres in Toronto, Vancouver and Montreal. The 1956/57 edition of the Register, issued jointly by our publishers and Kelly's Directories, includes a buyers' guide, listing alphabetically some 4,000 British products, and directories of over 4,500 British manufacturers, proprietary names and trade marks. It costs two guineas (postage 2s).

An appeal has been received from the secretary of the Wembley and District Group of the Multiple Sclerosis Society, asking for receivers for sufferers from multiple or disseminated sclerosis (previously known as "creeping paralysis"). They are also in need of sound recording equipment for gatherings organized by the Group. Offers of help should be addressed to the Honorary Secretary, R. A. L. Dumsday, 75, Rugby Avenue, Wembley, Middlesex.

Since the **advertisement pages** went to press Metropolitan-Vickers have asked us to point out that the supply voltage quoted in the specification of their miniature oscilloscope on page 86 is for overseas models. Those for the home market are for 200/250V, 50c/s supplies.

COVERAGE provided by the four stations of the latest Decca Navigator Chain—the North Scottish—which was inaugurated at the end of June, is shown on this diagram.

The address of the **Radio Advisory Service** (established by the Chamber of Shipping and the Liverpool Steam Ship Owners' Association), of which Capt. F. J. Wylie, R.N.(Retd.), is director, is now 7th Floor, 12-20 Camomile Street, London, E.C.3. (Tel.: Avenue 6941.)

WHAT THEY SAY

"**Electronics** is rapidly taking over electrical engineering education. Ten years from now electrical engineering will be synonymous with what to-day we call electronics. Electrical engineering of the pre-war era which concentrated its attention on phenomena at 60 cycles in general, and rotating machinery in particular, will be regarded as a small part of the broad subject of electronic science. Whether we will call it electrical engineering or electronics ten years from now I do not know."—Frederick E. Terman, Stanford University, California, in *Proc. I.R.E.*, June, 1956.

"**Wanted.**—TV aerial, preferably with fringe. Phone . . . . "—Advertisement in Provincial newspaper.

"**Resistor** fixed variable linear."—Label on box containing potentiometer in Ministry store.

BUSINESS NOTES

R. B. Pullin and Co., Ltd., of Great West Road, Middlesex, have concluded an agreement with the Kearfott Company, of America (a subsidiary of the General Precision Equipment Corporation), for the manufacture in this country of a range of Kearfott products, including servomotors and electronic components.

Substantial contracts for supplying the Services with equipment for testing drive units, transmitters and receivers for h.f. point-to-point communication systems have been awarded to **Marconi Instruments.**

James A. Jobling and Company, of Sunderland, the manufacturers of Pyrex heat-resisting glass, are producing Multiform glass parts for c.r.t. electrode assemblies and glass-to-metal seals. The Multiform process of manufacture from specially treated glass powders compressed in moulds and subsequently fused to form a uniform opaque glass was originally developed in the United States.

Closed-circuit industrial television equipment was recently installed by **Marconi's** at the Steel Company of Wales works at Port Talbot to facilitate the handling of ingots at the rolling mill.

The maintenance vehicles operated by four of the North Western Gas Board's South Lancashire groups (Manchester, Liverpool, Wirral and St. Helens) are now equipped with radio telephones. The latest installation, at St. Helens, by **Automatic Telephone & Electric Co.,** includes six mobile stations and a fixed station, the aerial for which is on top of a 225-foot gas holder.

Donvin Instruments, Limited, of Electrin Works, Winchester Street, Acton, London, W.3 (Tel.: Acorn 4995), now a member of the Pullin group of companies, is to specialize in the speedy repair and recalibration of all types and makes of indicating and measuring instruments.

Shandon Automation & Electronics, Limited, of 6, Cromwell Place, London, S.W.7, has been formed to produce industrial and scientific electronic equipment. It is associated with the Shandon Scientific Company of the same address (Tel.: Kensington 9001).

Permanently impregnated marking of customers' own p.v.c., rubber or Neoprene sleeving is undertaken by **Permark Service,** of Devon House, High Street, Cranleigh, Surrey. (Tel.: Cranleigh 499.)

The telephone number of **Aero Research, Limited,** Duxford, Cambridge, has been changed to Sawston 2121.

Cosmocord, Limited, have closed their Enfield factory and are now concentrated at their works at Eleanor Cross Road, Waltham Cross, Herts. (Tel.: Waltham Cross 5206.)

Standard Telephones & Cables have opened regional offices at Leeds (Norwich Union Buildings, City Square) and Glasgow (49, Queen Street, C.1).

Cementation (Muffelite), Ltd., manufacturers of anti-vibration mounts, have moved from 39 Victoria Street, S.W.1, to 20 Albert Embankment, London, S.E.11. (Tel.: Reliance 6556.)

The address of the **Willesden Transformer Company, Ltd.,** is now Manor Works, Manor Park Road, Harlesden, London, N.W.10 (Tel.: Elgar 5445).

OVERSEAS TRADE

A new monthly record of radio and electronic exports totalling nearly £3.4M in May is announced by the Radio Industry Council. The overseas sales of transmitting and navigational equipment totalled nearly £1.4M. The next highest of the five groups within the industry was sound reproducing equipment which totalled £731,000.

A report on the market for sound and television receivers in **Portugal** issued by the Export Services Branch of the Board of Trade shows that in 1954 (the last year quoted) Germany and the Netherlands supplied between them nearly 85% of the country's £600,000 radio imports. The United Kingdom's share dropped from 14% in 1951 to 7.5% in 1954 whilst during the same period Germany's share rose from 14% to 45% and by so doing displaced the Netherlands as the main supplier.

Switzerland.—An order for s.h.f. radio equipment to provide 600 telephone circuits between Berne and Geneva over a single radio channel has been placed with Standard Telephones & Cables through their associates, Standard Telephone et Radio S.A., Zurich. One repeater station, at Chasseral, will be used for the system which will be capable of being extended to provide additional r.f. channels either for telephone or television circuits.

Substantial quantities of radio-telephone equipment are being provided by Redifon for the **Iraq** police force. In addition to the equipment already supplied to the Baghdad police, which includes mobile four-channel v.h.f. transmitter-receivers and base stations, a number of h.f. transmitter-receivers (GR250) has now been ordered.

U.S.A.—Manufacturers contemplating participation in the World Trade Fair, which will be held in New York next April, are advised by the Board of Trade to get in touch with the London representative of the Fair, A. P. Wales, Dudley House, Southampton Street, London, W.C.2.

Transmitting equipment for three stations for air-to-ground communications on trans-polar air routes has been supplied by Marconi's for installation in **Greenland.** Each station is being equipped with two HC205 transmitters (one being a standby) which are designed to radiate up to three simultaneous telegraph or telephone transmissions on separate crystal-controlled h.f. channels.

The supply and installation of sound reproducing equipment in the six-storey General Hospital at Colombo, **Ceylon,** is being undertaken by Hadley Telephone and Sound Systems, of Smethwick, Birmingham. The installation will provide a four-channel service to 320 beds.

An agency for a low-priced five- or six-valve all-dry battery receiver of United Kingdom manufacture is being sought by **Narseys, Limited,** P.O. Box 145, **Suva,** Fiji. It should cover the short-wave bands between 16 and 37 metres and be fully tropicalized.

Colour Fundamentals

PRINCIPLES OF COLORIMETRY WITH PARTICULAR REFERENCE TO TELEVISION

By H. HENDERSON,* B.Sc., A.Inst P.

A NUMBER of articles have appeared in *Wireless World* in the last few months on the subject of colour television. The American N.T.S.C. system modified to British standards has so far received major attention. This is largely due to its being a two-way compatibility system which the Americans felt was essential to the successful launching of a new and expensive service. Such a requirement may not assume the same importance here and other systems are being tested. Whichever is finally chosen a full understanding of its operation will demand a knowledge of colorimetry and colorimetric terms. It is also true to say that a knowledge of the theory of colour is essential so that one may clearly recognize which equations derive from colour considerations and which are pure circuitry relations; these are often confused.

The Visible Spectrum.—There are at least 50 octaves in the electromagnetic spectrum. Visible light occupies less than one and extends from about 4,000 to 7,500 Angstrom units (1 Angstrom unit (Au) = 10^{-8}cm). The actual limits depend upon the observer and the intensity of the light. In practice the limits are taken as those wavelengths where the eye response is 10^{-2} of peak value, i.e., 3,800-7,800 Au.

The eye is not equally sensitive to the wavelengths present in this band but has a peak of sensitivity in the yellow-green as shown in Fig. 1. This curve may be obtained by measuring the energy required for each wavelength to match a given brightness, then plotting the reciprocal of energy required against wavelength. A photocell with a filter having an overall response of the same shape as the luminosity curve would give equal outputs when illuminated by lights of different colours which are judged by the eye to be equally bright. Once a standard luminosity curve for the average eye is agreed, such photocells may be used for photometric work with much greater convenience.

A black and white television camera should have such a colour response if it is to transmit brightness information faithfully.

Colour Perception.—It is useful to assume that the eye contains three wideband receptors, one sensitive to the middle region of the spectrum, one to the blue and one to the red end. The colour sensation produced in the brain depends upon the relative excitations of these receptors. It follows that any colour, whatever the mixture of wavelengths in its composition, can be matched by suitable mixtures of three colours, red, green and blue, each stimulating the appropriate receptor to the same extent as the matched colour. These three colours are referred to as the primaries and they may be monochromatic or wideband. For colorimetry the primaries are monochromatic and are generally red (7,000 Au), green (5,461 Au) and blue (4,358 Au). In colour television the three primaries used for colour matching are the three phosphor colours found in the colour receiver. Suitable activation and combination of the light output from these phosphors may produce any colour match and it is the camera's function to produce signals of suitable amplitudes to achieve this.

Additive and Subtractive Mixing.—The process of combining coloured lights referred to above is known as additive colour mixing and for this purpose the primaries are red, green and blue. The mixture colours obtained by combination of these primaries may be represented qualitatively by means of a triangle as shown in Fig. 2.

As blue and yellow together in suitable amounts match white they are referred to as complementary colours. Other complementary colours are red and cyan, green and magenta.

Where the colours of pigments and filters are involved—that is, things which have no colour in their own right—the process of mixing is a subtractive one. For example a yellow filter is one which absorbs blue from light falling upon it and allows red and green to pass. It is often referred to as a "minus blue" filter. Similarly a magenta filter is a "minus green" and a cyan filter is a "minus red." Yellow, magenta and cyan are the primaries of subtractive colour mixing. If a yellow filter is followed by a cyan filter and white light falls on the system, yellow subtracts blue, cyan subtracts red, and only green emerges.

In this sense cyan and yellow make green. The colours obtained by subtractive processes are indicated in the triangle shown in Fig. 3.

Colorimetry.—Colour is measured by first matching the chosen colour with a suitable mixture of red, green and blue light and then quoting the amounts of each primary present in the mixture. The ratio of the three amounts specifies the colour. Doubling each primary contribution does not change the colour but only its brightness.

Two units are available for the measurement of the amount of each primary in the match. One derives from photometry and is the lumen. The other is the trichromatic unit, which will be dealt with later. A lumen of any colour appears equally bright. It follows from the luminosity curve (Fig. 1) that a lumen of yellowish-green light contains least energy. A standard candle, treated for the moment as an omnidirectional point source of light, gives off light at the rate of 4π lumens. This may be taken as the definition of the lumen. The photocell with the eye-response filter mentioned earlier will give outputs directly proportional to the number of lumens falling on it.

Supposing white were to be matched by light from the three cathode-ray tube phosphors (as

*Engineering Training Dept., B.B.C.

used at present), it might be found that 1 lumen of white is matched by 0.3 lumens of red plus 0.59 lumens of green plus 0.11 lumens of blue. This may be written

1 lumen of white $\equiv 0.3(R)+0.59(G)+0.11(B)$.

Notice that the luminance of the mixture colour is the sum of the luminances of its components. These quantities are important and continually recur in colour television literature. If different phosphors are used they will need modification.

Because of the unequal values assigned to the amounts of red, green and blue to match white,

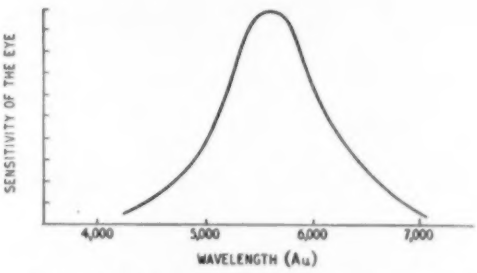
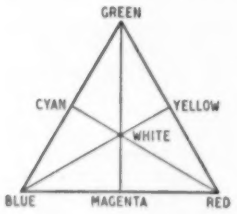
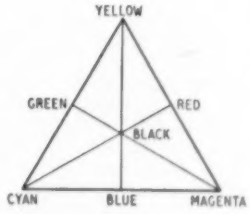


Fig. 1. Curve showing the sensitivity of the eye with different wavelengths of light (in Ångstrom units).



Left: Fig. 2. Colour triangle illustrating the additive mixing of coloured lights.

Right: Fig. 3. Colour triangle illustrating the subtractive mixing of colours by filters.



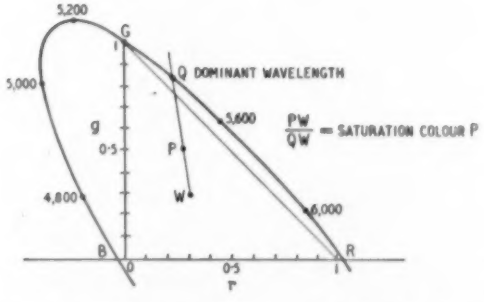


Fig. 4. Spectrum locus diagram. Note that white (point W) occurs at r=g=0.33.

which is regarded as unbiased to any particular colour, a different unit is favoured, and is of particular convenience in colour television. This unit is defined by the statement that 1 unit of red+1 unit of green +1 unit of blue match 1 lumen of white

or 1 lumen of white $\equiv 1(R)+1(G)+1(B)$.

These units are referred to as trichromatic units or T-units. To preserve the law of additivity 1 lumen of white is taken as equal to 3 T-units

$\therefore$ 1 T-unit of white $\equiv 0.33(R)+0.33(G)+0.33(B)$.

If we are still thinking of the same white as above and the c.r.t. phosphors it follows that

1 T-unit of red = 0.3 lumens

1 T-unit of green = 0.59 lumens

1 T-unit of blue = 0.11 lumens.

When a colour is quoted as matched by so many T-units of red, green and blue, its brightness can be found by multiplying the red T-units by 0.3, the green by 0.59 and the blue by 0.11 and adding.

At present the electrical outputs from the red, green and blue camera tubes are adjusted to be equa. when the camera is looking at the standard whitel The camera outputs are in effect then in T-units. To obtain a signal proportional to brightness it is necessary to multiply the red output by 0.3, the green by 0.59, the blue by 0.11 and add. Thus we have the often recurring equation

Luminance signal $E_Y = 0.3\,E_R + 0.59E_G + 0.11E_B$

where E_R, E_G and E_B are the camera outputs when looking at the particular colour and they would be equal if the colour were standard white.

Standard White.—There is unfortunately no single standard white. Equal-energy white is the white observed when all spectral colours are present with equal energy—this is somewhat blue. What is known as Illuminant B is the white of direct sunlight while Illuminant C is the white of sky-scattered sunlight. Illuminants B and C may be obtained by placing suitable filters in front of a tungsten lamp—known as Illuminant A. The figures quoted above refer to Illuminant C.

The Colour Triangle.—If a colour be matched by R T-units of red, G T-units of green and B T-units of blue, this may be written:—

(R + B + G) T-units of colour $\equiv$ R(R) + G(G) + B(B)

or 1 T-unit of colour $\equiv$

$$\frac{R}{R+B+G}(R)+\frac{G}{R+B+G}(G)+\frac{B}{R+B+G}(B)$$

Now write

$$r=\frac{R}{R+B+G},\qquad g=\frac{G}{R+B+G}\ \text{etc.}$$

then 1 T-unit of colour $\equiv r(R)+g(G)+b(B)$

where $r+g+b=1$

The values of any two coefficients, say r and g, specify the original colour without any reference to its brightness. These two quantities can be plotted and a colour triangle based on the primaries chosen is obtained. If now each colour of the visible spectrum is treated in this way and its colour point is plotted as in Fig. 4, a continuous line is obtained which is called the spectrum locus. It will be observed that many r and g values appear together greater than unity and some are in fact negative. What is the significance of negative colour? Here the truth must be revealed that it is in fact not possible to match all colours by suitable mixtures of

three primary colours. Taking sodium light as a single example, it is possible to come fairly close to a match with red and green primary mixtures. If blue is added to the sodium light, however, a match can be obtained. Thus:

sodium yellow + blue ≡ red and green

or allowing mathematical processes to intrude

sodium yellow ≡ red + green − blue

the amounts of the three primaries being measured in T-units.

In fact all colours lying outside the RGB triangle cannot be matched by the three chosen primaries and no real colour can exist outside the spectrum locus. Between the red and blue end lie the purples, the non-spectral colours which are mixtures of red and blue.

Properties of the Colour Triangle.—If two colours represented by two points on the diagram are mixed, the mixture colour lies on the line joining these points. Where it lies depends on the relative amounts of each colour used. Colours lying at the extremities of a line passing through white are called complementary colours, for suitable mixtures of complementary colours match white.

A colour may be specified on such a diagram by drawing a line through the colour point (P), and white (W), and producing it to cut the spectrum locus at a point (Q), corresponding to some particular wavelength called the dominant wavelength. The ratio of the distance of the point from the white point to the distance from the spectrum locus to the white point measures the purity or saturation of the colour. Dominant wavelength and saturation specify the colour. A suitable mixture of white and the dominant wavelength would match the colour. The presence of white in a colour desaturates it—it becomes paler; for instance red tends to pink. Dominant wavelength and saturation thus offer an alternative means of specifying colour.

Colours of No Brightness.—Once negative amounts of colour are accepted it must follow that there are points on the diagram corresponding to colours having no brightness. The brightness, it may be remembered, may be obtained by multiplying the T-units of each primary by the appropriate factors (0.3, 0.59 and 0.11).

i.e., brightness $= 0.3r + 0.59g + 0.11b$

If this is zero we have:—

$$0 = 0.3r + 0.59g + 0.11b$$

but $r + g + b = 1$

$$\therefore 0 = 0.3r + 0.59g + 0.11(1 - r + g)$$

i.e., $0 = 0.19r + 0.48g + 0.11$

This is the equation of a straight line. Colours lying on this line have no brightness. The line is called the alychne and will have importance in the later development of the subject. Fortunately this line does not pass through the region of real colours so that we are not faced in practice with colours of no brightness. They would no doubt be singularly difficult to detect! Below this line lie colours of "negative brightness."

Colours of Surfaces.—A surface is coloured by virtue of the light it reflects after selective absorption of the incident illumination. Because the spectrum locus is fairly straight between greenish-yellow and red it follows that mixtures of spectral colours in this region will themselves be on the spectrum locus. A wide spectral band may be reflected from a surface, i.e., it will appear bright, and yet it can have a saturated colour if the reflected colours lie between greenish-yellow and red. Yellow and orange are in consequence usually bright saturated colours.

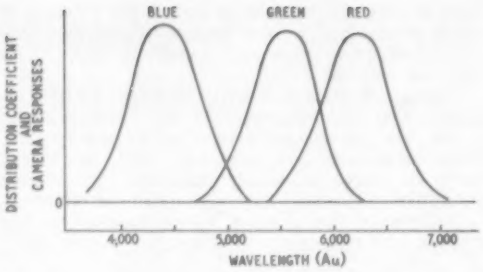


Fig 5. Red, green and blue distribution coefficients.

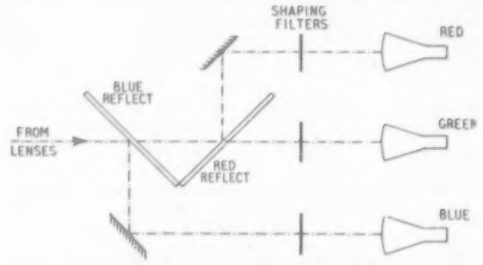


Fig. 6. Method of splitting light into three colour components in a colour television camera.

Because the spectrum locus in the green region of the spectrum is so convex it follows that any wide band of reflected light in this region of the spectrum will inevitably produce a mixture colour which lies within the spectrum locus, i.e., a desaturated colour. Thus, bright greens are invariably desaturated greens. Saturated greens are very dull. At the blue end of the spectrum the eye sensitivity is falling away and saturated blues are also very dull colours. These facts are important when choosing the primary colours to be used for matching. It is more important to be able to match saturated yellows and oranges than greeny blues as the last-mentioned only occur at very low brightness levels.

Colour Analysis.—The colour television receiver should produce a coloured picture which matches at every point the colour of the original scene. This means that the camera outputs must control the point by point magnitudes of the red, green and blue phosphor brightnesses. A close connection must therefore exist between the colours of the primary phosphors and the colour filters used in the camera.

To obtain the overall camera response curves, the standard white is imagined split up into a large number of narrow spectral bands and each band in turn is matched by measured amounts of red, green and blue primary. A plot of these amounts (distribution coefficients) against wavelength give curves of the sort shown in Fig. 5. As the addition of all the wavelengths gives the standard white so the areas under the three curves are equal, for equal quantities of red, green and blue are, by definition, required to match this white. The colour responses of the red, green and blue cameras must have the shape of these curves.

It is not, of course, possible to cater for the negative-going portions of the response curves in the

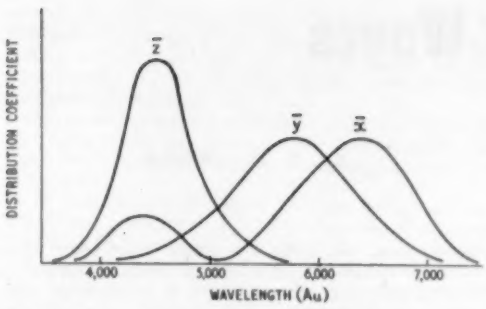


Fig. 7. Plot of distribution coefficients $\bar{x}$, $\bar{y}$ and $\bar{z}$.

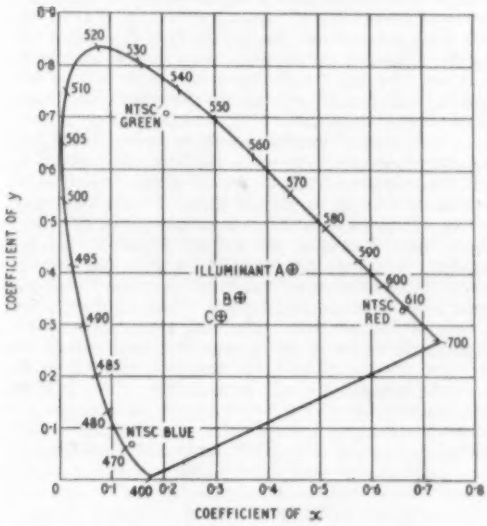


Fig. 8. C.I.E. trichromatic co-ordinates with spectrum wavelengths in millimicrons, Illuminants A, B and C, and N.T.S.C. primaries.

present state of the art. This implies, as has been stated earlier, that only colours lying within the RGB triangle formed by the phosphor colours can be accurately matched.

The light falling on the colour camera may be split into three components by devices known as dichroic mirrors, as shown in Fig. 6. One mirror reflects the blue end of the spectrum and transmits the rest. The second reflects the red end of the spectrum and transmits the remainder which is a band in the middle of the spectrum. The reflection (or transmission) wavelength characteristic of the dichroics multiplied by the camera's characteristic may approximate quite well to the desired response for analysis. In general, however, further filters are required and they are known as shaping filters.

International Colour Specification.—Colour points and triangles referred to earlier depend entirely on the original choice of the three primary colours. Figures mentioned have been derived from primaries which are the phosphors at present in use in colour tubes. For accurate and reproducible colour measurement such primaries would be undesirable and in practice monochromatic colours from the red, green and blue regions of the spectrum are chosen (7000Au—red, 5461Au—green and 4358Au—blue).

These colours are not easy to produce at any great level of brightness or with simple apparatus and many experimenters would prefer to use different primaries. It is clear, however, that no comparison of the work by one experimenter with that of another is possible unless the results of one can be translated from one set of primaries to another.

The three monochromatic colours mentioned above might well have been chosen as the basis of international colour specification and all those desirous of communicating their results to others would have translated their practical observations taken with their own primaries to the international ones. This is a straightforward process once it is known where one set of primaries lie on the RGB diagram of the other; it is just a question of mathematics.

As any such transformations are possible it was decided to choose three primary colour points for the international specification of colour which would dispose of negative values for colour co-ordinates, i.e., the triangle formed by three such points must completely enclose the spectrum locus. The points must therefore lie outside it and will represent imaginary or super-saturated colours. This triangle is referred to as the XYZ triangle. X and Z lie on the alychne and are therefore "colours" of no brightness. Y is chosen so that the line YX lies along the straight portion of the spectrum locus. This means that many spectrum colours are specified by YX values alone.

By means of a change of axes the XYZ triangle can be made a right-angled triangle and the white point (this time equal-energy white) arranged to be at $x = 0.3$, $y = 0.3$. This is the C.I.E. chromaticity diagram and represents the international reference frame for colour specification.

A plot of the distribution coefficients $\bar{x}$, $\bar{y}$ and $\bar{z}$ gives curves as shown in Fig. 7 (the bars over the letters being used to distinguish distribution coefficients from trichromatic coefficients). It may be observed that the $\bar{y}$ curve has the shape of the luminosity curve referred to at the beginning of this article. This implies that X and Z values contain no brightness information and this is a consequence, of course, of choosing X and Z to lie on the alychne.

No negative-going portions exist as the whole of the spectrum locus lies within the XYZ triangle. Filter photocell arrangements can be made to have responses of the shape of the $\bar{x}$, $\bar{y}$, $\bar{z}$ curves shown in Fig. 7. With three such cells nothing is easier than to determine the C.I.E. chromaticity of a particular light source. The output of each cell when illuminated with equal-energy white (obtained by means of a suitable filter over a tungsten lamp) is made equal (electrically—say by means of a variable meter shunt). Each cell is then illuminated with the colour to be measured and the X, Y and Z outputs noted. Y gives the relative brightness of this colour to the white. The chromaticity co-ordinates are then

$$x = \frac{X}{X + Y + Z}, \quad y = \frac{Y}{X + Y + Z},$$

$$\text{and } z = \frac{Z}{X + Y + Z}$$

and the x, y values are plotted. A number of points obtained in this way are shown on the diagram Fig. 8.

Looking at Square Waves

A Direct Approach to the Interpretation of Distortion

By T. D. CROOK

THE advanced textbooks on electronic subjects apply mathematical analysis to the question of what happens to a square wave in passing through an amplifier, and fill their pages with exponentials; or perhaps soften up the problem by a determined brandishing of mathematical atom bombs in the shape of Laplace transforms, or Heaviside operators —all of which leave the average not-too-mathematical enthusiast trudging along miles behind, and very likely regarding the whole business as akin to devilry, or as just clever examples of "Senior Wrangling." The real "amateurs' books," on the other hand—and particularly two modern American ones—sometimes include in their illustrations examples of square-wave distortion that never were on land or sea, and also provide interpretations which are often quite erroneous.

It is possible, however, to explain the process of square-wave distortion in an amplifier by simple physical methods, and though (apart from "Cathode Ray's" famous series of articles) descriptive explanations may seem to be rather *infra dig.* in a paper such as *Wireless World*, an attempt in this direction may perhaps not come too much amiss, particularly when augmented by diagrams which show the amount of variation in frequency response and phase-shift indicated by different degrees and kinds of wave-form distortion. Therefore, leaving the mathematicians to their fun and games I will endeavour to explain to fellow readers the results of much reading and a few experiments.

As is so well known that I am repeating it here, all regularly recurring wave-forms—square, triangular, pulsed, or as "wiggly" as you please—can be shown to be built up from sine waves, and a Fourier series shows that to produce a square wave of amplitude A and frequency f, the following recipe is essential:—

1. A sine wave of frequency f and amplitude $4A/\pi$.
2. Another sine wave of frequency $3f$ and amplitude $4A/3\pi$.
3. Another sine wave of frequency $5f$ and amplitude $4A/5\pi$

and so on using all the odd harmonics of f in the proportions indicated, theoretically up to infinity.

Incidentally all the sine-wave harmonics must be in phase with the fundamental; if one takes the same recipe but adds the harmonics in antiphase the resulting concoction is a sharply peaked wave-form —a culinary *contretemps* which would puzzle Philip Harben no end!

If such a square wave is pushed through an amplifier which either attenuates or accentuates the higher harmonics, it is obvious that its wave shape will be somewhat changed in the process—but in what way, and why?

A rough physical idea of the how and why is gained by concentrating on the "verticals" of the square wave. The quotes here have their common ironical significance, since the "verticals" are never truly vertical: if a good square wave is produced on a c.r.o. screen, and then the time base is speeded up sufficiently, these verticals will be found to have a decided slope, showing that they take a definite time (as represented by distance along the horizontal axis) to be traced out. This "rise-time" is, of course, the standard test of an amplifier's high-frequency response. Now if the verticals are thought of as being produced by one "side" of a sine wave with a frequency 100 times (say) that of the square wave and of the same amplitude, it is obvious that at a time-base speed slow enough to show several complete square waves the "sides" of the sine wave would be indistinguishable from a vertical trace, though there would, of course, be fifty of them to each horizontal of the square wave. Thus it seems physically more than likely that it is the higher harmonics of the square wave that are together responsible for the verticals, despite their continual decrease in amplitude with increasing frequency. In fact, if we draw a bow at venture and claim that attenuation of the higher harmonics of the square wave will reduce the straight upright part of the verticals, and accentuation will lengthen them, a practical test shows that we are toxophilites of no mean order, for this is just what does happen: attenuation of the square wave's higher harmonics rounds off the leading (left-hand to you) edge of the wave-form to an increasing degree till eventually, with large attenuation, no vertical part remains; accentuation lengthens the verticals, producing pronounced peaks, or over-shoots, which very rapidly drop back to their proper horizontal level. The two effects are shown in Figs. 5 and 6 respectively.

The above reasoning may seem to be a rather shady piece of "Junior Wrangling"—more *post hoc* than *propter hoc*, in fact—but it is generally true,

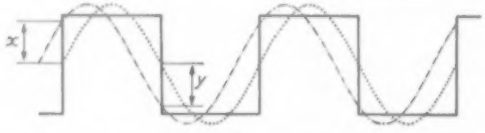


Fig. 1. Square wave with its sine-wave fundamental (dotted line), and the same fundamental with a phase-lead (dashed line).

Fig. 2. Square wave with its sine-wave fundamental (dotted line), and the same fundamental after attenuation without phase-shift.

though of course the problem is complicated first by the fact that *all* the harmonics above the amplifier's turn-over point are affected, and, secondly, by the co-existence of phase-shift, which has its own undetermined effect.

However, at the low-frequency end the effects of variation in response and of phase-shift are quite distinct, and both amenable to a direct diagrammatic explanation.

A possible square-wave frequency for a low-frequency test might be 50 c/s, and if such a square wave is injected into an amplifier so decidedly "Low-Fi" that its response begins to fall off at 5 kc/s (the 100th harmonic of 50 c/s), the verticals and edges of the wave will still be reproduced in all their pristine perfection, since all harmonics up to the 99th are being fully catered for. On the other hand, since the square wave contains no frequencies below its fundamental, provided this is passed through without phase-shift or amplitude variation, the output square wave will be a replica of the input. Thus if the amplifier included a fantastic filter which allowed it to have perfect response at 50 c/s, but negligible response with appalling phase-shift at 45 c/s, it would still reproduce perfectly a 50 c/s square wave. This fact is emphasized because more than one book which deals with this subject implies or states that square-wave distortion gives an indication of amplifier response below the square-wave frequency. One could, by extrapolation from existing distortion, deduce the probable response below the square-wave frequency, but extrapolation can be a snare (cf. Scroggie's "Radio Laboratory Handbook," p. 355). As an example, one Williamson amplifier had a small peak at around 10 c/s: a test with a 15-c/s square wave might show perfect response, whereas 10 c/s would reveal the slight peak. If then the amplifier has phase-shift or change in amplification at 50 c/s, what sort of distorted square wave will come out of its spout? And why?

Phase-shift

First, the effect produced by phase-shift. Fig. 1 shows a square wave on to which has been superimposed as a dotted line its sine-wave fundamental, whose amplitude is $4/\pi$ times that of the square wave. The two wave-forms are of course exactly in phase with each other. If after passing through the amplifier the phase of the fundamental is given a lead of 5°, say, without any appreciable variation in gain (as would normally be the case), its new position would be as shown by the dashed line. Incidentally with only 5° phase-shift at the fundamental, the amount taking place at the 3rd harmonic (150 c/s) would be nearly negligible. The result of this shift in the position of the fundamental relative to the original square wave will obviously be to lift the leading edge by the amount x, and to drop the trailing edge by the amount y, and in actual fact all other points on the horizontal are similarly raised or lowered to such a degree that the horizontal remains quite straight, but tilts, as shown in Fig. 3(a). The actual amount of tilt for 5° shift is about 12% —i.e., the corners are lifted or dropped by an amount equal to 12% of the whole vertical side of the wave. In just the same way a phase-lag—shifting the fundamental to the right on the diagram—would cause the same amount of tilt, but in the opposite direction. The shift shown in the diagram has of course been

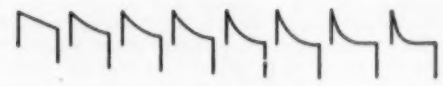


Fig. 3. Diagrams showing square-wave distortion when the fundamental is attenuated (with phase-shift) to the following degrees: (a) negligible attenuation; (b), 0.9 (−1 dB); (c), 0.8 (−2 dB); (d), 0.7 (−3 dB); (e), 0.6 (−4.5 dB); (f), 0.5 (−6 db); (g), 0.4 (−8 dB); (h), 0.3 (−10.5 dB).

Fig. 4. Diagrams showing square-wave distortion when the fundamental is accentuated (with phase-shift) to the following degrees: (a), "flat" condition; (b), 1.2 (+1.5 dB); (c), 1.4 (+3 dB); (d), 1.6 (+4 dB); (e), 1.8 (+5 dB); (f) 2 (+6 dB); (g), 3 (+9.5 dB).

exaggerated for clearness. As a detector of phase-shift the method is very sensitive, and as little as 1° shift causes a noticeable tilt.

Secondly, amplitude attenuation or accentuation. Fig. 2 shows a square wave with its normal sine-wave fundamental, but this time the fundamental (dashed line) has been reduced in amplitude but not shifted in phase (unlikely, but assumed for clearness). If only the fundamental is affected, the result will be to lower the middle of the horizontal by the amount z, leaving the ends unaffected, and also to lower all other points so that the horizontal now curves downwards. This concave curvature is the indication of falling response at the fundamental, and when this is so large that some drop also occurs at the 3rd and perhaps 5th harmonic as well, the wave-form begins to take on an exponential shape, as shown in Fig. 3(e). If there is accentuation of the fundamental it is also apparent that the curvature will be convex, instead of concave.

Normally, of course, the two effects appear together, but phase-shift always shows up first. As stated above, a 5° phase-shift gives 12% tilt, which is very easily seen, but the change in amplification that accompanies this in a normal R-C-coupled amplifier can be shown to be about ½%, or 0.04 dB, which would produce a quite undetectable amount of curvature in the horizontals. Fig. 3(b) shows the amount of curvature produced by a 1-dB drop at the fundamental: it is quite small, but the tilt for the corresponding phase-shift is pronounced. The normal falling-off in low frequency response due to the increasing reactance of coupling capacitors causes a phase lead, whereas the normal "bass-lift" tone-control causes a phase lag: the latter effect can be seen in Fig. 4, where, owing to the bass-lift circuit, the normal phase-lead produced in the "flat" position is overridden and eventually turned into a large phase lag, with a tilt in the opposite direction.

If a band-stop filter is included which removes a narrow band of frequencies centred on f, one gets practically the same result as for normal l.f. attenuation, with the difference that the loss at f is very high, whereas that occurring at $3f$, $5f$, etc., is much less than would take place when the falling

response was due to normal R-C couplings. In this case the horizontals show a deep central dip which slopes evenly up to the corners. If the band of frequencies removed is situated at the h.f. end, the horizontals have a sharp narrow dip near the leading edges. There may be a mathematical explanation or analysis of this, but I doubt if it can be explained in physical terms.

The above descriptive explanations may be debatable, and perhaps of limited interest, but it is hoped that the diagrams may prove to be of practical value.

Measurement of phase-shift is of less importance in audio work, since the ear is insensitive to it, and in any case equalizers and tone-controls necessarily produce phase-shift—though surely a perfect record characteristic equalizer should restore the correct phase relations that were altered by the circuits used in the recording process. Since, however, the main amplifier should cause minimum phase-shift, square waves can easily be used to ascertain the amount it does produce by applying the formula: Sin $\theta = \pi x/4$, where θ is the phase-shift in degrees at the testing frequency, and x is the fraction of the whole vertical side of the square wave that any corner is moved away from its normal position by the phase-shift tilt.

Amplitude Variations

More important are variations in amplification over the audio band. Unfortunately it is impossible to apply any method for measuring the actual curvature produced, owing to the simultaneous phase-shift effect, and to the fact that the curves soon take on an exponential shape. Therefore a series of tracings were made from a c.r.o. screen under specified conditions, and these do give a fairly accurate idea of the amount of gain or loss involved.

The equipment used for this purpose was—apart from a sine/square-wave generator—part of a pre-amplifier having the Williamson low-pass sharp-cut filter (used in its "flat" position), and the Baxandall tone-control. Tests showed that these circuits had only about 1 dB loss at 25 kc/s, and the output connections to the c.r.o. were taken direct to the Y-plate, under which conditions the c.r.o. would produce perfect square waves at 10 c/s and 20 kc/s. In any case small deficiences in the whole set-up could be corrected at the start of each measurement by very small adjustments to the tone control: actually the correct "flat" position of the control could best be found, especially on h.f. tests, by ensuring that a good square wave was produced. The Baxandall tone-control has a peak in its response well above the audio range, and to ensure that this did not vitiate the results the h.f. tests were carried out mainly at 1 kc/s, using up to about 3 kc/s when a large "drop" or "lift" was required. In any case the diagrams are intended to be useful only for audio work when the normal types of R-C voltage amplifiers would be used.

Procedure at l.f. was as follows. A 50-c/s square wave was passed through the amplifier and into the c.r.o., and the bass control adjusted to its "flat" position. The resulting trace, Fig. 3(a), shows that there was considerable phase-shift, but no visible attenuation, as the slopes are quite straight. The square wave was then changed to a sine wave, also at 50 c/s and the c.r.o. tracing adjusted to give a peak-to-peak reading of 10 divisions on the calibrated screen, the tone control was then moved to reduce

Fig. 5. Diagrams showing square-wave distortion when there is 6 dB loss at the stated multiples of the square-wave frequency (f): (a) 10f; (b), 5f; (c), 3f; (d), 2f; (e), at f.

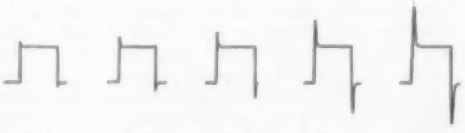


Fig. 6. Diagrams (except e) showing square-wave distortion when there is the stated amount of over-amplification at 10 times f: (a), 1.1 (1 dB); (b), 1.2 (1.5 dB); (c) 1.4 (3 dB); (d), 2 (6 dB); (e), 2 (6 dB) at 5f.

the response at this frequency to 9 divisions, a drop of about 1 dB. The wave-form was then returned to a square-wave shape, and the actual wave-form on the screen was traced through transparent paper, giving the result shown in Fig. 3(b). The whole process was repeated, with the bass control adjusted to reduce the gain at 50 c/s from 10 to 8 divisions, and the resulting wave-form again traced, as in Fig. 3(c). Other values down to 10.5 dB drop were also obtained as shown. The same procedure was used to deal with given values of "lift" at 50 c/s, as in Figs. 4(a)-(g).

The diagrams are, of course, independent of frequency, although actually made at 50 c/s, and in the cases where they represent only a small attenuation at the square-wave frequency, it can be assumed that there is a drop at this frequency only, and none at $3f$ even; where there is a large drop at f, there is likely to be some drop at $3f$ too, but in any case the response curve is that of a typical tone control, and should apply with a minimum of error to any normal audio amplifier. Therefore, in order to test the l.f. response of an amplifier, one need only pass through it a square wave of 75 c/s, say, adjusting the c.r.o. sweep speed so that the wave-form is about the same size as that in the diagrams, and reduce the freqency until a suitable amount of curvature is produced, when the attenuation at the test frequency can be estimated with reasonable accuracy from the diagrams given.

H.F. Response

The procedure at the upper end of the audio band is more complicated, and the results unfortunately less certain in their significance, since in this case *all* the square-wave harmonics above the amplifier's turn-over point are attenuated to a steadily increasing degree, and at a rate depending on the nature of the response curve above that point. Luckily the response usually falls off at about the same rate for normal types of amplifier, but it may possess a noticeable rise at supersonic frequencies, as when negative feedback is applied over a transformer. Nevertheless, I think that the appended diagrams for h.f. response would have a general application.

To produce the diagrams, first a 1-kc/s square wave was used, and the treble control adjusted

slightly to give a good square-wave shape. The input was then changed to a 9-kc/s square wave, and the output set to give a 10-division trace, as before, which was reduced by the treble control to 5 divisions—a drop of 6 dB at 9 kc/s. The original 1-kc/s square wave was then again injected, and the new wave-shape traced, as in Fig. 5(a), showing the effect of a 6 dB drop at the 9th harmonic of the square wave, with an increasing drop above that frequency. Similar tests produced the diagrams in Figs. 5(b) to (e), for a 6 dB drop at 5 kc/s, 3 kc/s, 2 kc/s and 1 kc/s, respectively, when using a 1-kc/s square wave. Actually, as mentioned above, a slightly higher square-wave frequency had to be used when the tone-control was unable to give sufficient drop, but the *proportions* between the square wave and the harmonic frequency at which the attenuation was taken were kept the same, and the resulting change in amplifier response to the much higher square-wave harmonics (only 1 dB down at 25 kc/s as stated above) should not have made any really marked changes in the wave-shape. Note that with the 6 dB drop occurring at $2f$, the output square-wave amplitude was about 13/14ths of its original value, since there was also a few dB drop at f as well; also with 6 dB drop at the fundamental, f, the amplitude of the output (now far from square) was about 0.7 of its original value. It is also worth noticing the difference between the square-wave distortions produced by attenuating the fundamental 6 dB when working at the l.f. end, and so having only small simultaneous attenuations at $3f$ and perhaps $5f$, but full reproduction of all harmonics from $7f$ onwards (Fig. 3(f)), and attenuating the fundamental 6 dB, and *all* higher harmonics to an increasing degree, as when working at the h.f. end (Fig. 5(e)).

The effects caused by "top-lift" were traced in the same way, except that four values of "lift" were used at 9 kc/s, and one at 5 kc/s, giving the results shown in Figs. 6(a) to (e).

Again, as suggested for the l.f. end, if a 1-kc/s square wave is passed through an amplifier, and the frequency increased until the corners become rounded, about as in Fig. 5(a), it can be assumed that there is about 6 dB drop at $9f$, if the response curve above that point falls off at a normal rate, as would usually be the case. As an illustration of what happens when the response curve is abnormal, a test was made with a 5-kc/s square wave which was reproduced quite well when all controls were in the "flat" position, but when the sharp-cut filter was switched to its 12-kc/s position, the square wave was converted to a somewhat triangular-shaped sine-wave. In this position of the filter there was 6 dB drop at 12 kc/s with an attenuation of some 30 dB per octave above this frequency, and a slight rise at a considerably higher frequency: the more-or-less complete removal of the 5th and higher harmonics of the square wave completely destroyed its shape.

Luckily no normal "straight" amplifier or pre-amplifier has this kind of h.f. response curve: one gets it only by the use of parallel-T networks, negative feedback, and expensive 1% resistors and capacitors—and then, if like me you are no connoisseur of antique 78 r.p.m. records, you hardly ever have occasion to use it!

"Unconventional F.M. Receiver"

Correction.—On page 261 of the June issue the core of B4 Ferroxcube should be list No. FX.1146 (as in Fig. 6). The list No. FX.1595 refers to the B2 Ferroxcube core tried as an alternative.

TELEVISION PICTURE QUALITY

***This comparison of the relative definitions offered by different television systems appeared as an Editorial in the July number of our associated journal* Wireless Engineer.**

ALTHOUGH there is no immediate prospect of a colour television system coming into operation in this country, there is a good deal of discussion going on about the standards which should be adopted. There is a school of thought which considers that compatability with the present black-and-white television service is unnecessary and that when colour does come it can be, or even should be, on different standards.

A view which is quite often expressed is that Great Britain should adopt the same colour standards as the Continent and there is good reason to believe that this means a 625-line version of the American N.T.S.C. system. There is, of course, no suggestion that the present 405-line system should be abandoned so far as monochrome transmission in Bands I and III are concerned. The suggestion is that no attempt should be made to introduce colour into these but that colour should be developed as a parallel service in Bands IV and V.

Although superficially attractive, there are a good many objections which can be raised against such a scheme. We do not propose to discuss them now, however, for we are more concerned with the underlying idea that 625 lines is a more suitable standard for television than 405 lines. In some circles, it seems to be taken for granted that it is greatly superior. The fact that the Continent only adopted 625 lines after a lengthy examination of our 405-line and the American 525-line systems is often thought to be evidence of its superiority.

We ourselves think that they made a mistake in choosing their standards. We thought so at the time and, having seen 625-line television, we still think so. We do not mean that the 405-line system is better than the 625-line. What we do mean is that the 625-line system does not make the best

use of the 5-Mc/s bandwidth allotted to it. We feel strongly that, for this bandwidth, the number of lines should be around 500 and that this would give better pictures than either 405 or 625 lines.

The important factors concerned with this matter of lines are not always as clearly realized as they should be. We propose, therefore, to compare them for the two existing systems.

First of all, in the 405-line system there are 377 active lines; that is, lines conveying visible picture information. In the 625-line system there are 575 active lines. There is no doubt at all that, in respect of vertical definition, the 625-line system is $575/377 = 1.53$ times as good as the 405-line. This improvement of 53% in vertical definition is accompanied by a proportional reduction in the visibility of the line structure, which is in itself a good thing. Too much importance should not be attached to it, however, for methods exist (e.g., spot-wobble) by which the visibility of the line structure can be reduced.

In the horizontal direction, the definition depends on the velocity of the scanning spot and the bandwidth. It is quite usual to assess horizontal definition in terms of a chess-board type of pattern. The fundamental component of the waveform produced by scanning such a pattern is a sinusoid of which one cycle corresponds to two adjacent elements of the chess-board. If the duration of the active part of a line is τ_1 and there are n elements per line, the duration of one cycle of this sine wave is $2\tau_1/n$. The frequency is thus $n/2\tau_1$ and this is taken as the upper limit of the video bandwidth.

This is rather an arbitrary relation, but it is practically useful and, in any case, it is valid for comparing different systems. With 405 lines, the frequency is 3 Mc/s and τ_1 is 80.95 μ sec. Therefore, $n = 2 \times 3 \times 80.95 = 485.7$ elements per line. With 625 lines, the frequency used is 5 Mc/s and τ_1 is 52.32 μ sec, so $n = 2 \times 5 \times 52.32 = 523.2$ elements per line. The horizontal definition is thus $523.2/485.7 = 1.075$ times that of the 405-line; that is, an improvement of 7.5%.

The facts are thus, that 625 lines gives 53% better vertical and 7.5% better horizontal definition than 405 lines. For this, it requires a greater bandwidth. The video bandwidth is greater in the ratio of $5/3 = 1.66$ and the channel bandwidth (i.e., the band occupied by both sound and vision transmissions) in the ratio $7/5 = 1.4$.

The aspect ratio is 4/3 in both cases. With 405 lines, there are $485.7 \times 3/4 = 364$ elements in the same linear distance as the 377 active lines. The definition is thus virtually the same in both the vertical and horizontal directions. With 625 lines, there are $523.2 \times 3/4 = 392$ elements in the same linear distance as the 575 active lines. The vertical definition is thus $575/392 = 1.46$ times as good as the horizontal.

It is clear that the 625-line system gives better definition than the 405-line but at the expense of 40% more channel width. The improvement is almost entirely in vertical definition. For practical purposes the two are virtually the same in horizontal definition.

If the bandwidth is kept constant, altering the number of lines improves the definition in one direction across the picture at the expense of the other. It is clear that there must be an optimum number of lines and it is not unreasonable to suppose that it occurs when the definitions in the two directions are the same, as in the 405-line system. If the two are not the same, in which direction should the definition be the better? We ourselves feel that horizontal definition is more important.

In support of this view, we instance the following:—

(a) In the cinema, the tendency is all to wide screens, emphasizing the horizontal direction.

(b) In laboratory tests of 405-line and 625-line pictures, each having the bandwidth of its particular standard, we find it hard to say with certainty which is which, unless there is a direct comparison.

(c) In laboratory tests of the 405-line system with unrestricted bandwidth against 625 lines with 5-Mc/s bandwidth, we find that the 405-line system gives the better picture.

In the 625-line system, the extra 2 Mc/s of bandwidth is used almost entirely to increase the vertical definition. It is this that we think wrong. We think that 405 lines with a 5-Mc/s bandwidth would give a better picture. We do not say, however, that the proper number of lines for this bandwidth is 405. Probably the right thing to do is to keep the definition in both directions the same and, for 5-Mc/s bandwidth, that means about 500 lines, as we said earlier.

It should be unnecessary but, in view of the figure of 500, perhaps we should point out that this does not mean that we think the American 525-line standard is the right one. That has a 60-c/s frame frequency and a 4-Mc/s bandwidth and gives inferior horizontal definition to the 405-line system.

In saying all this, we are not advocating any change of standards by anyone. So far as monochrome television is concerned, that is impracticable. What we are concerned about is that, if the introduction of colour is made on standards other than 405 lines, the new standards should be the right ones. If it is practicable to have different standards for colour, we do not think that 625 lines with 5-Mc/s bandwidth is right. For this bandwidth, 500 lines or so would be better but, better still, would be 625 lines with the 7.4-Mc/s bandwidth necessary to equalize the definition in the two directions.

W. T. C.

Four-speed Record Changer

A NEW version of the "Monarch" automatic record changer (type UA8) has been introduced with a choice of four turntable speeds including 16⅔ r.p.m. for "talking book" records. The new mechanism includes a neutral position in which the jockey wheel is disengaged from the motor spindle, and particular attention has been given to the reduction of "rumble." There is provision for manual operation of single records and the playing weight of the pickup arm is adjustable. Power consumption of the 4-pole motor is 8 watts at 240 V, 50 c/s.

The makers are Birmingham Sound Reproducers, Ltd., Old Hill, Staffordshire.

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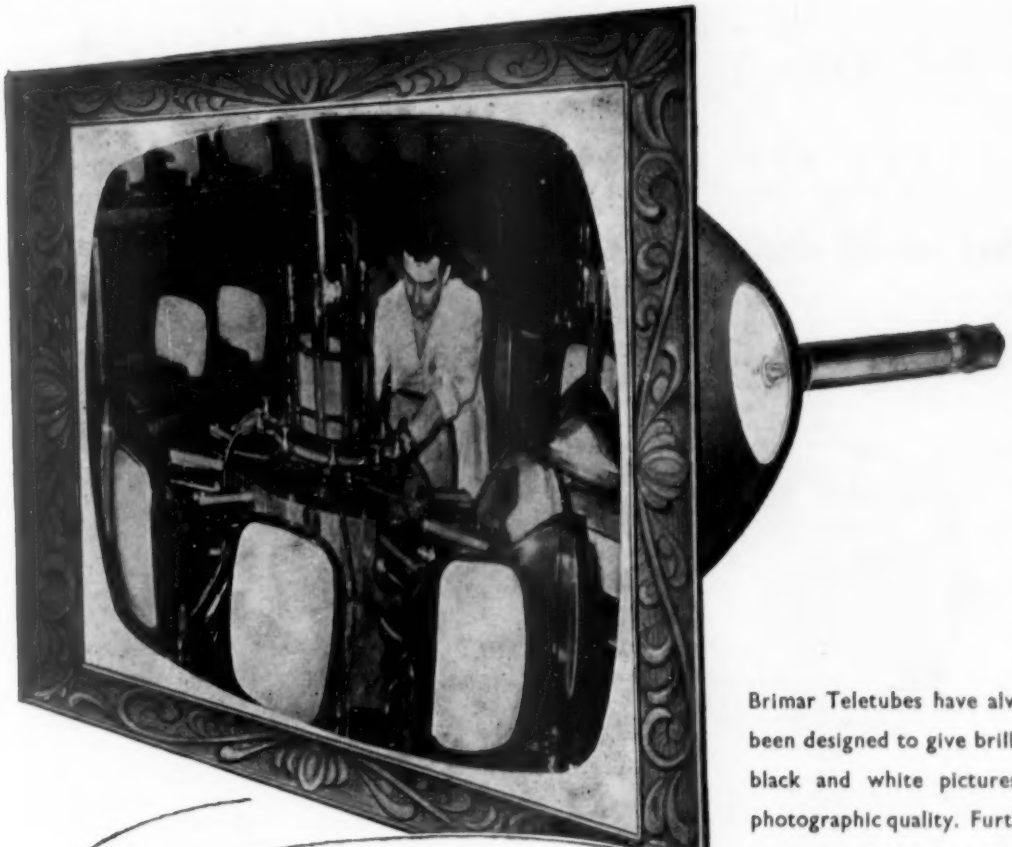

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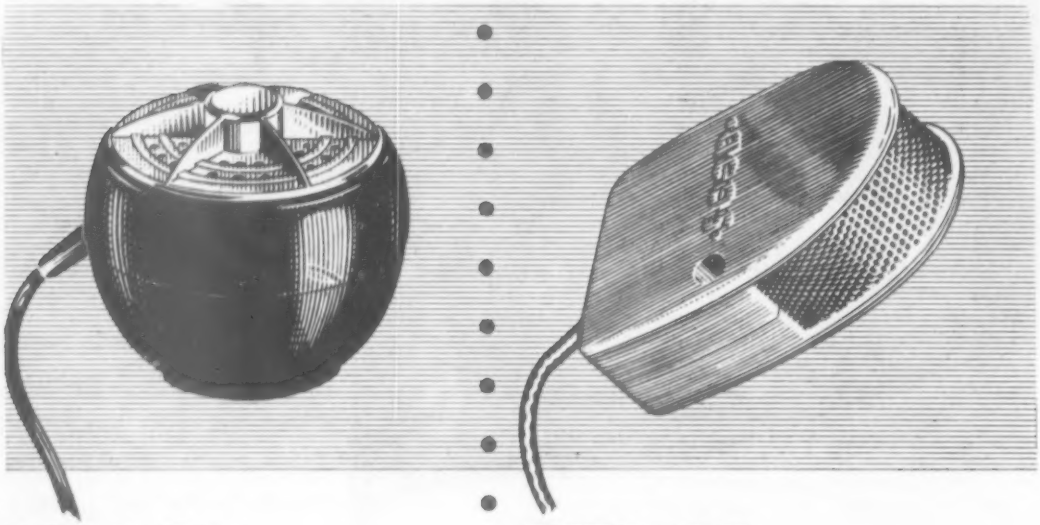

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Servo Tuning System

A great deal has been heard about servomechanisms recently in connection with electronic control devices for automatic factories. This article gives an example of how a servo system is designed for a particular application, and has added interest because the application is in the field of radio.

Remote Position Control of Transmitter Tuning Elements

By D. SMART

THE ground-to-air radio communications system of an airport has to be arranged so that any of the frequencies allocated for aircraft approach or landing control can be used without delay. This could be done by having a number of transmitters tuned to the different predetermined frequencies. By far the most economical solution, however, is to use a single multi-tuned transmitter with remote selection facilities. An example of this is a 1-kW transmitter designed by Redifon which can be pretuned to ten frequencies in the 2-26 Mc/s range, any one of which may be selected from a remote operating position. The maximum distance between the remote control point and the transmitter is limited only by the loop resistance of the single pair of control wires required for remote switching, modulating and keying. This loop resistance must not exceed 1,000 ohms, which means that control distances up to 25 miles can be achieved.

Fig. 1 shows a simplified diagram of the r.f. circuit. A ten-position crystal oscillator feeds into an aperiodic buffer stage, ensuring maximum frequency stability. This is followed by another buffer stage with tuned anode load which feeds a driver stage for the power amplifier. Crystal and waveband selection are carried out by solenoid-operated switches. Within each band, however, a two-to-one frequency coverage is needed, and this involves continuously variable elements. It can be seen from Fig. 1 that three such elements are involved, viz., driver tuning capacitor, p.a. tuning coil, and aerial loading capacitor. For automatic tuning to any of ten preset channels some means of accurately resetting these three variables had to be devised.

The difficulties entailed in engineering a purely mechanical system with the necessary degree of accuracy and reliability, coupled with simplicity required for production, were judged too great. It was therefore decided to concentrate on an electromechanical servo system which combined accuracy and simplicity.

A simple remote position-control servo system of the form shown in Fig. 2 was finally adopted. This is commonly known as a self-balancing bridge system. The two potentiometers R_1 and R_2 connected across the voltage supply form the bridge. The amplifier input is connected across the potentiometer slides and constitutes the bridge load. When the bridge is balanced there is no potential across the slides. Under these conditions there is no input to the amplifier and no resultant motion of the motor and load. When the slider of the setting potentiometer R_s is moved from its initial position, a potential is developed across the input of the amplifier. This is amplified and drives the

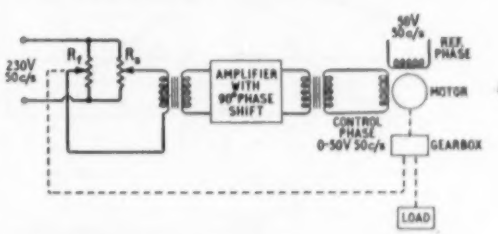


Fig. 2. Schematic of the remote position-control servo system used for tuning.

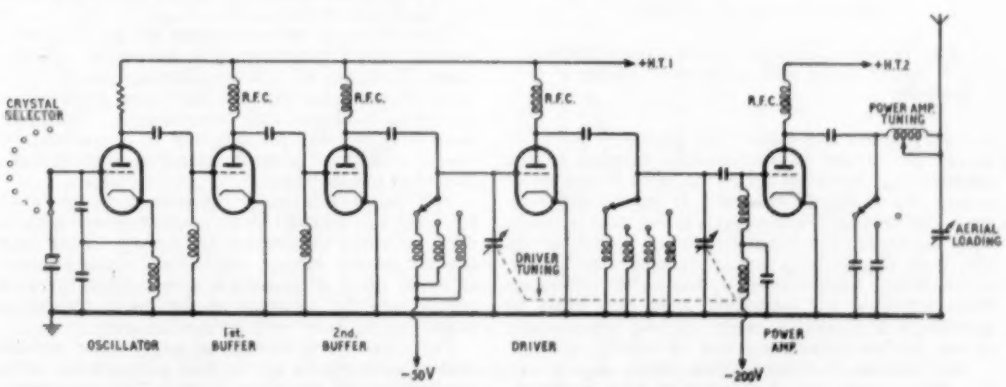


Fig. 1. Simplified diagram of the r.f. circuit of the transmitter.

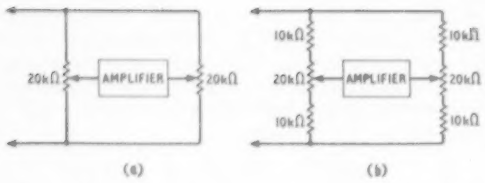


Fig. 3. Angular- to voltage-error translator: (a) simplified bridge network: (b) actual circuit.

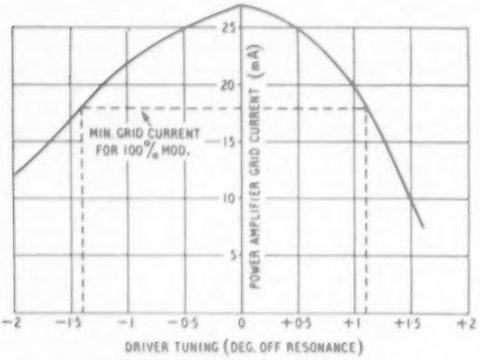


Fig. 4. Curve showing variation of power-amplifier grid current with angular error in the driver tuning of the transmitter.

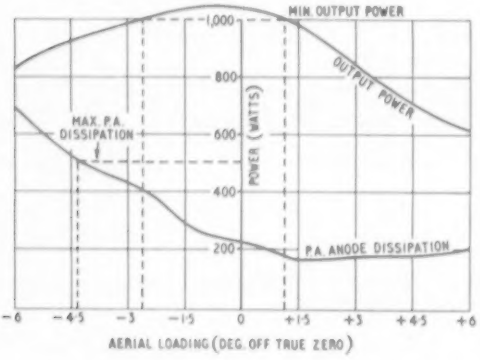


Fig. 5. Variation of output power and p.a. anode dissipation with angular tuning error in the aerial loading of the transmitter.

motor, gearbox and load. The follow-up potentiometer (R_f) slider is mechanically coupled to the gearbox and therefore moves in such a way as to restore the bridge to balance. It can be seen that by sufficient amplification this sytem can be made very sensitive to potentiometer setting, thus achieving the high degree of accuracy required for tuning applications. Furthermore, by having ten setting-up potentiometers and switching from one slider to another, it is possible to make the load move to any of ten predetermined positions or tuning points.

Any remote position-control servo system can be broken down into a number of basic elements. As they operate by virtue of an intial positional

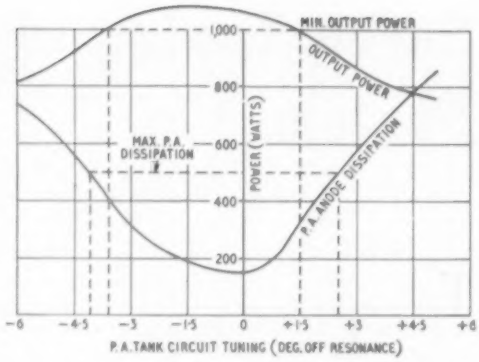


Fig. 6. Variation of output power and p.a. anode dissipation with angular tuning error in the p.a. tank circuit of the transmitter.

error between the input and output members, there must always be some error-measuring device. This angular error can be written down as

$$\theta = \theta_i - \theta_o \qquad .. \qquad (1)$$

where θ_i = input angle, θ_o = output angle and θ = error angle

and is converted into a voltage error, the magnitude and phase of which must correspond to the magnitude and direction of the angular error. The angular- to voltage-error translator is shown in Fig. 3; (a) is the bridge network in a simplified state, while the actual circuit is at (b). The object of the 10-kΩ series resistors is to keep the impedance presented to the amplifier at balance more constant. This makes the system sensitivity more constant over the potentiometer range. With the values shown the impedance varies by 25%. The higher the value of R the smaller will be the percentage variation in impedance. This, however, calls for a larger voltage supply across the bridge or greater amplifier gain for a given sensitivity. The bridge is energized by 230 volts, 50c/s, which is the most convenient supply available. Although the use of a higher frequency supply, e.g., 400 c/s, would have considerably eased the design of the amplifier, this was not considered important enough to offset the disadvantage of having to provide a 400-c/s generator in an equipment where the servos are an important but small part of the whole.

The follow-up potentiometers are ten-turn wirewound helical potentiometers having an effective angle of rotation of 3,600°. They consist of 11,500 turns of resistance wire, giving a very good voltage resolution combined with compactness. This makes them very suitable for coupling to a gearbox. It can be seen that the error voltage is developed at a rate of 30 mV/degree.

The thirty setting-up potentiometers are again ten-turn wirewound helical potentiometers with an effective angle of rotation of 3,600°. They have slightly poorer voltage resolution, consisting only of 6,500 turns of resistance wire. This, however, affects only the accuracy of the initial setting-up, which can be made very great with care.

The equation of motion of any remote position control servo can be set up from a knowledge of the accelerating and retarding forces. The accelerating force is $K\theta$, where K = controller factor, i.e.,

output torque per unit angle error in oz-ins/radian. The retarding forces are given by the product of the output moment of inertia and output angular acceleration $\left(J \frac{d^2\theta_o}{dt^2}\right)$, plus the product of the friction coefficient and output speed $\left(F \frac{d\theta_o}{dt}\right)$, where J = output moment of inertia in oz-ins² and F = friction torque per unit output speed in oz-ins sec/radian.

$$\text{Thus } K\theta = J \frac{d^2\theta_o}{dt^2} + F \frac{d\theta_o}{dt} \quad .. \quad .. \quad (2)$$

θ_o increases linearly with time at a rate determined only by the motor speed and gear ratio: thus

$$\theta_o = \omega_o t \quad .. \quad .. \quad .. \quad .. \quad (3)$$

$$\therefore \frac{d\theta_o}{dt} = \omega_o \quad .. \quad .. \quad .. \quad .. \quad (4)$$

$$\text{and } \frac{d^2\theta_o}{dt^2} = 0 \quad .. \quad .. \quad .. \quad .. \quad (5)$$

Substituting (4) and (5) in (2) we have

$$K\theta = F\omega_o$$

$$\therefore \theta = \frac{F\omega_o}{K} \quad .. \quad .. \quad .. \quad .. \quad (6)$$

Equation (6) gives the steady state error in terms of output speed and system parameters. It would appear that by sufficient amplification, i.e., making K large, θ can be made very small. There is a limit, however, to how large K can be made without incurring instability. This can be seen by examining the transient solution to equation (2). This is not dealt with in this article because of its length and complexity. In practice K was made variable and adjusted to achieve a compromise between accuracy and prolonged oscillation.

The design procedure applied to all three servos was as follows:—

(1) Knowing θ, F and ω_o, K was calculated from equation (6).

(2) Knowing the error volts per radian and the motor torque per volt, the required amplifier gain was calculated.

It was first necessary to determine the resetting accuracy required of all three servos. Figs. 4, 5 and 6 show how p.a. grid current, power output and p.a. anode dissipation vary with angular error in tuning. From these it is possible to determine the maximum error permissible in each case. These are:

- ± 1.08° for aerial loading capacitor servo.
- ± 1.1° for driver tuning capacitor servo.
- ± 1.5° for p.a. tuning coil servo.

We shall consider only the aerial loading capacitor servo in detail. One important requirement was that the time required to change channels should be as small as possible. This means that the servos should have fairly high output speed. In the case of the aerial loading capacitor, with an angle of rotation of 180°, the gear ratio was made 400 : 1 between motor and load. This results in a maximum operating time of 5 seconds for a motor speed of 3,000 r.p.m.

The static friction in the system, mainly introduced by the follow-up potentiometer and gearbox, determines the minimum starting torque, hence the size of motor required. It was found to be 2 oz-ins. A two-phase servo motor with the following characteristics was chosen: moment of inertia, 0.16 oz-in²; stalled torque, 4 oz-ins; reference phase, 50 volts 8.6 watts; control phase, 50 volts 11 watts.

Fig 7, curve (b), gives the torque *v.* speed characteristic of this motor. It can be seen that the friction damping introduced by the motor

$$F = \frac{\Delta T}{\Delta S} = \frac{4 \text{ oz-ins}}{3{,}000 \text{ r.p.m.}} = \frac{4}{3{,}000 \times 2\pi/60}$$

$$= 0.012 \frac{\text{oz-in}}{\text{rad/sec}}$$

or $0.012 \times 400^2 \frac{\text{oz-ins}}{\text{rad/sec}}$ at the output shaft.

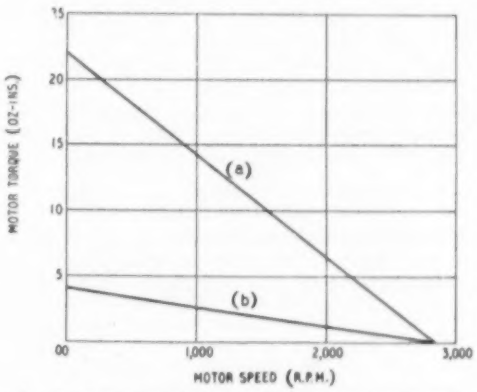


Fig. 7. Torque/speed characteristic of the electric motor used in the servo system.

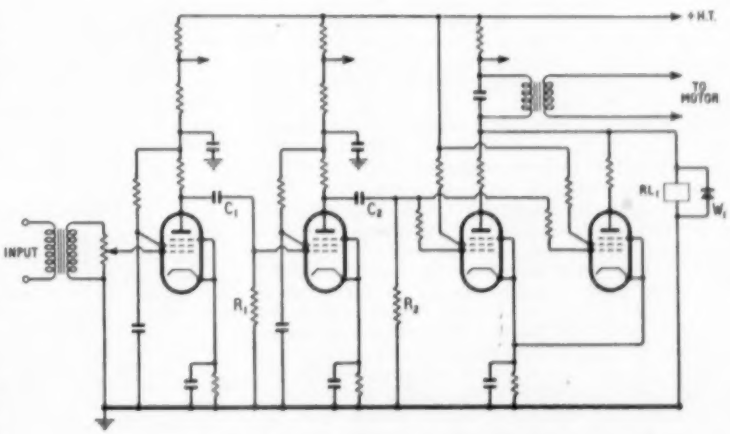


Fig. 8. Circuit of the 10-watt servo amplifier.

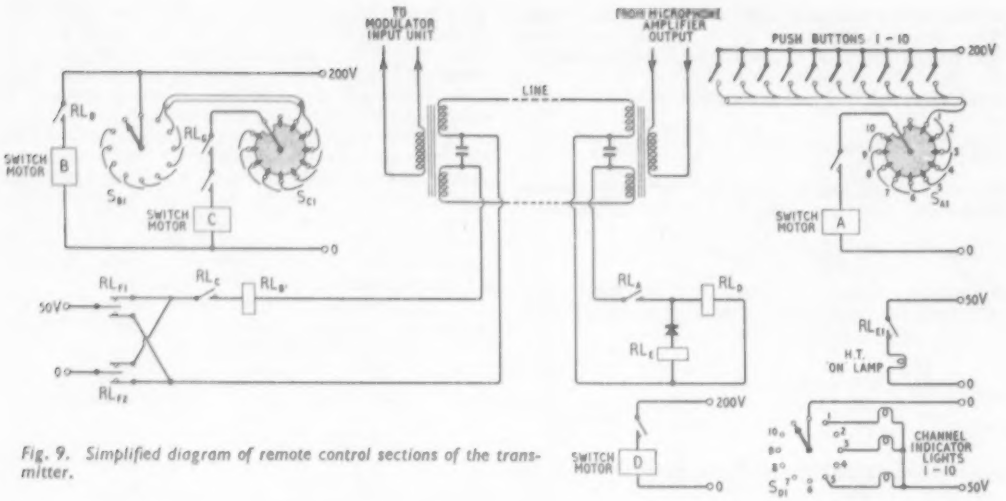


Fig. 9. Simplified diagram of remote control sections of the transmitter.

The output speed was $\omega_o = 0.785$ rad/sec. Knowing F, ω_o and θ

$$K = \frac{0.012 \times 0.785 \times 400^2}{0.019} = 7.93 \times 10^4 \frac{\text{oz-ins}}{\text{rad}}$$

The error volts are 30 mV/degree or 1.72 volts/rad. The motor torque is 0.08 oz-ins/volts or 0.08 × 400 oz-ins/volts at the output shaft. Therefore

$$\text{amplifier gain} = \frac{7.93 \times 10^4}{0.08 \times 400 \times 1.72.} = 1{,}440.$$

The amplifier circuit is shown in Fig. 8. It can be seen to consist of two pentode voltage amplifiers driving a power output stage consisting of two valves in parallel. The noise level is 60dB below full output of 10 watts. The interstage coupling components C_1R_1 and C_2R_2 are arranged to introduce a 90° phase shift at the operating frequency (50 c/s). This ensures that the reference phase of the motor can be fed from the mains via a step-down transformer without the need of a phase-shifting network. The relay and rectifier (RL_1, W_1) form part of an arrangement for switching off the h.t. from the p.a. during the tuning operation. It ensures that no h.t. is applied until all three servos are stationary. In practice the servo comes to rest with two overshoots and one undershoot, and the resetting accuracy is greater than anticipated.

Fig. 9 shows a simplified diagram of the remote control sections of the transmitter. Use is made in these of similar solenoid-operated rotary switches, to those employed for waveband selection. Two modes of operation are possible with these switches. In the first, application of the operating volts to a suitable contact on the "homing wafer" causes the switch to "motor" round to the desired position, when the supply is broken and the switch comes to rest. In the second mode, the solenoid is pulsed by suitable current pulses. Both these modes of operation are used in the remote control section.

Assuming the normal switching-on procedure has been carried out, the remote selection of frequency is carried out as follows. Switch motor A at the remote end is made to "motor" to the position (1—10) selected by depressing an appropriate push-button switch (1—10). In doing so its associated relay contact RL_A keys the line. Relay RL_B, at the transmitter end, is energized by the pulses produced by relay RL_A. Relay RL_B "pulses" switch motor B to the desired position. After a short delay switch motor C is made to "motor" to the same position by means of a wafer on switch motor B and delayed relay contact RL_G. In doing so its associated relay RL_C keys the line again. The pulses are used to energize relay RL_D which "pulses" switch motor D to the appropriate position. The latter part of the operation is merely "signalling back" that the correct position has been selected at the transmitter.

Switch motor B also controls a similar switch, the master selector switch, which controls all the tuning potentiometers' sliders and wavechange switches. This master selector switch can also be controlled locally by means of a switch on the front panel of the transmitter power supply bay. Full local control is thus possible in the event of line failure, etc.

When all the tuning operations have been carried out, after a short delay the h.t. is applied. The p.a. cathode current which flows operates a relay ($RL_{F1\cdot2}$) which reverses the polarity of the 50 volts d.c. on the line. This causes relay RL_E at the remote end to be energized and indicates that the transmitter is operating satisfactorily. All the normal overload protection methods are, of course, also included.

Thermistor Thermometer

FOR medical research the low heat capacity and rapid response of the thermistor, when connected to measure temperature, has obvious advantages, and much interest was shown in a brief description of an American instrument which appeared in our April issue (p. 164).

We understand that a British-made thermistor skin thermometer is in production by Chapman Anderson, Ltd., 7, Oak Hill Park, London, N.W.3. The basic element is the S.T.C. Type F thermistor and the instrument is designed for use with ordinary flashlamp batteries. An industrial version for measuring surface temperatures is also available with a scale calibrated from 0 to 300°C.

"BELLING-LEE" NOTES

By the time you are reading this, it will be common knowledge that our television test transmitter G9AED has been purchased by the Independent Television Authority, and will be doing its job on their behalf from Emley Moor. We will continue to take an interest in the performance of the equipment.

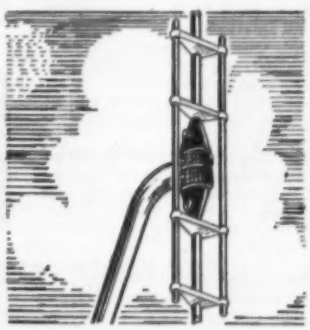
We will be asking for reports from the trade, and we ask all readers in the area to let us know how they receive the test signals and on what type of aerial. The reports will all be acknowledged by Q.S.L. card, and will be entered on a large map of the area which will be published as a service to anyone who is interested or who requires to know what can be expected.

It is expected that the first signals will be radiated on Monday, July 2nd, but at the time of writing we do not know the time schedule.

We try to be particularly careful not to take sides between our very old and good friends the B.B.C. and the newcomers to our industry—the I.T.A. But we do feel it is a pity that so many viewers, particularly in Lancashire, don't do justice to I.T.A., by not putting up the appropriate aerial and then adversely criticizing the technical quality of the I.T.V. picture received on a B.B.C. aerial. We know that these are locations of strong signal and where "in-line" conditions prevail under which the I.T.V. signal is adequate with a B.B.C. aerial, but there are tens of thousands of cases where a band III aerial would show an incomparably improved picture.

To continue this discussion a little further, if a band III channel 9 signal is received on a band I channel 2 aerial, the signal is more than 10 dB down on band III. The addition of the "Belling-Lee" adaptor kit* to a band I "H" has been known to increase the band III signal by as much as 18 dB, though we would not claim this gain in every case. What it all amounts to is that you can only hope to have a comparable balanced picture using a B.B.C. "H" if you are in such a location that you have considerably more than 10 dB useful signal than is required, and if your picture is free from interference and ghost.

Quite a number of people ask why it is necessary or desirable to radiate a test signal for, say, three months prior to the official opening of a new transmitter. Of course, the answer is to give the trade—the radio dealers—an opportunity to arrange conversions where necessary, and to erect or modify aerials. In general, by the very nature of band III, multi-element aerials are required, and all multi-element aerials are very directional, so much so that it is just not worth while trying to orientate aerials on compass bearing, a signal really is necessary anywhere other than in the swamp areas. There are hundreds of thousands of aerials to be erected, and they take time. Emley Moor main transmitter will not open up till some time in October, short days and indifferent weather don't lend themselves to quick work on the rooftops—and viewers can be very impatient once the alternative programmes are available. It isn't so much the programme that matters as the ability to change from one to the other.



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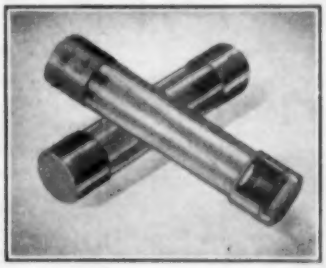

In the manufacture of these fuse-links the unique internal soldering technique bonds caps, elements and glass into one unit. The possibility of caps becoming loose is remote. This method of construction applies to ratings from 500 mA up to 25 A. Lower ratings, down to 60 mA, are at present supplied in our original design, in which we have minimised the problems that are obviated by the "all-in-one" construction.

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AUGUST/56 IC.68A

LETTERS TO THE EDITOR

The Editor does not necessarily endorse the opinions expressed by his correspondents

"*Unconventional F.M. Receiver*"

CONGRATULATIONS to Mr. Scroggie (and to *Wireless World*) on again breaking new ground even though the a.f.c. method may call for second thoughts. I don't think Mr. Banks' method (February issue) is the answer either; devices where the error signal itself applies the correction are inherently unstable and tend to oscillate (or "hunt" as the control instrument engineer would word it).

I don't mean that Mr. Banks' device does not work. Merely that the circumstance that it does not hunt is almost certainly fortuitous and consequently is not readily reproduced.

Could it be, therefore, that the real answer to this a.f.c. problem lies with the voltage sensitive capacitors mentioned in the April issue (p. 175) and may we have some more details regarding them?

Hornchurch, Essex. L. D. STUART.

Unconventional Interference

I REALLY must protest at what M. G. Scroggie refers to as "a less awkward band," when explaining his choice of a local oscillator frequency in his article on an unconventional f.m. receiver in the June issue.

If my mathematics are correct, this would be the band between 29.33 and 31.33 Mc/s, part of which is in the ten-metre amateur band.

With propagation m.u.fs on the increase due to the rise in the sunspot cycle, this band provides no less a measure of enjoyment to many hundreds of British amateurs than does v.h.f. to those who have adopted this method of receiving B.B.C. programmes. I suggest Mr. Scroggie might be reminded that tolerable receiver oscillator radiation in the various bands of the radio frequency spectrum have been conventionally agreed by the industry.

The harmful interference radiated by this unconventional receiver (the author admits this with respect to Band I television), arises from a very inferior design which can have no place in the present advanced state of this branch of science.

The distasteful way in which the interference is deliberately removed from a broadcast to a non-broadcast band is no credit to the writer, and *Wireless World* is cheapened by the publication of such material.

London, S.E.25. DAVID DEACON (G3BCM).

The Author Replies:

I AM sorry that the description of my precautions against interference should have been open to such misinterpretation as that put on it by David Deacon. May I therefore call attention to the following points:

(1) I did not admit that the type of receiver I described "radiates harmful interference."

(2) Even if, as a result of its being designed contrary to my recommendation, it were to do so on Band I, this would not necessarily mean that the design described interferes in the 29.32-31.45 Mc/s band. The vulnerability of Channel I televiewers to oscillation in the band 44-47 Mc/s, to which I referred, is far greater than that of amateurs to oscillation between 29.32 and 31.45 Mc/s, in the following respects:

(a) The strength of radiation is likely to be substantially greater. As I pointed out, use of the lower frequency "still further reduces radiation."

(b) Whereas radiation on *any* frequency between 44 and 47 Mc/s inevitably comes within the reception band of *every* Channel I receiver, only about one-sixth of the 29.32-31.45 Mc/s band comes within only about one-fifth of the 10-metre amateur band, and at any given time occupies only one of perhaps 20 telephony channels within that fifth.

(c) The number of Channel I televiewers is vastly greater than the amateurs necessarily working within that particular one-fifth of that particular band.

(d) Television receivers, being usually present in the same house, and often only a few feet away on the other side of a party wall, are liable to be affected by a source of radiation that would be inappreciable even a dozen yards away.

(3) No reason has been given for concluding that this "very inferior" unconventional receiver radiates any more than conventional types; in fact, quite the contrary.

(4) An oscillator is not one of the unconventional features of my receiver; it is included in almost every receiver in the world. Millions of receivers, products of "the present advanced state of this branch of science," have no r.f. stage to separate the frequency changer from the aerial, and their continuously tunable oscillators sweep across the whole of the amateur 7 and 14-Mc/s bands. Why does Mr. Deacon not turn his fire on them? By contrast, my receiver has a r.f. stage, an exceptionally low oscillator frequency for a Band II receiver, and a much higher ratio between the receiving and oscillator frequencies than any conventional type. Moreover its oscillator works only on a few spot frequencies.

On the whole, then, I feel there is no immediate cause for alarm.

M. G. SCROGGIE.

Two-channel Stereophonic Sound Systems

IN reply to the questions raised by P. B. Vanderlyn and Ian Leslie in the July issue the following comments may help to clarify the situation.

First, the statement in the above article that "the reproduced sound image is more accurately positioned if arrival time differences are overruled and the sound image is positioned by intensity differences only" was not meant to apply to the sounds actually at the two ears of the listener. What was meant was that the sounds at the loudspeakers should differ only in intensity level and that for the best stereophonic effect the listener should be seated so that there is no overall time difference between the sounds from the loudspeakers for the hearing mechanism as a whole. The fact that there must be a small time difference between the sounds at the individual ears when the sound image is not in the centre was not meant to be included in this statement. That such a time difference is produced, with unequal intensities at the loudspeakers, is well appreciated. For off-centre listening this criterion obviously no longer holds, but it has been found that fairly satisfactory compensation can be applied, as was shown in the article.

Secondly the theory underlying P. B. Vanderlyn's remarks, although apparently straightforward, does not in practice appear to agree very well with the results obtained experimentally using speech or other sounds of a very irregular nature. This is not altogether surprising since the hearing mechanism is not at all simple in its operation. The fact that only a difference in the sound level at the loudspeakers of between 12 dB and 18 dB is necessary to give the impression of "hard over"

to one side is certainly not confirmed by this theory. Experimental results of other investigators[1, 2] confirm this finding. An alternative theory[3], although with limitations, is also in agreement. The figure of 12 dB difference for "hard over" used in obtaining the microphone responses was sufficient to give this sensation for all the subjects tested.

Referring to Ian Leslie's comment about the controversy over loudspeakers, it is agreed that this difference should be settled. The results given in the article agree quite closely with the work of other investigators[4, 5, 6] and although the results might be subject to experimental error it is felt that the specified correction is definitely needed. To obtain this correction by using directional loudspeakers, although simple, cannot be said to be perfect; but it does result in very much improved results.

Tone controls are still needed to correct for scale distortion due to different listening levels to the original and to compensate for the acoustics of the listening room. Also, studio engineers are after all only human and it is nice to be able to correct for differences of opinion between them and oneself.

Ruislip, Middx. D. M. LEAKEY.

REFERENCES

[1] W. B. Snow, *J. Acoust. Soc. Amer.*, Nov. 1954.
[2] V. L. Jordan, *Acustica* Vol. 4, No. 1, 1954.
[3] J. C. Steinberg and W. B. Snow, *Electrical Engineering*., Jan. 1934.
[4] H. Haas, *Acustica*, Vol. 1, No. 2, 1951.

Three Minutes' Silence

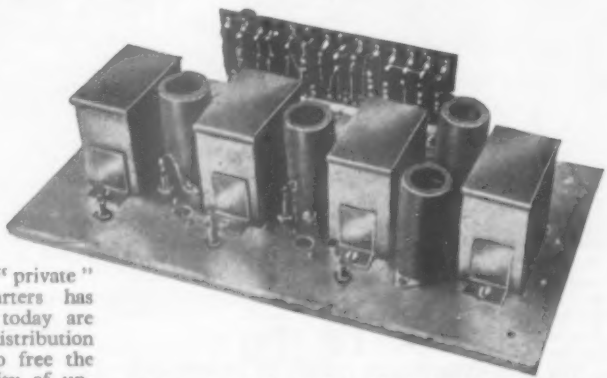
THOUGH not a professional marine radio operator, I have done a good deal of listening on the 500-kc/s channel and so can make an unbiased comment on "Free Grid's" observations (May issue) about alleged non-observance of the three minutes' silence. My experience is that a fairly pronounced silence descends on the channel at 15 and 45 minutes past the hour. In fact, if anyone is looking out for "600-metre Dx," as I still do, these silence periods are very profitable.

AS3.

Wide-Band Linear R.F. Amplifier

For Use in Ships' Communal Aerial Systems

By B. F. DAVIES,* A.M.I.E.E.



SINCE the last war the need for the "private" broadcast receiver in the crew's quarters has been recognized and many new ships today are planned to be fitted with an aerial distribution system. In many cases this is done to free the ship's superstructure from the multiplicity of unsightly wires that would otherwise appear as more of the crew obtained receivers. In a small ship a multiplicity of "private" aerial wires may constitute a positive danger by altering the calibration of the d.f. loops and in oil tankers there is a fire hazard if sparking occurs in a badly installed aerial when the ship's MCW transmitter is working.

The obvious solution is to install one "official" aerial for broadcast reception and to serve all receiving points through a wide-band r.f. amplifier and coaxial cables.

Basic Requirements.—Considering the aerial first, it will be appreciated that the position, height and length of the aerial will be largely dictated by the layout of the ship and the position of the transmitting aerials. Difficulties are greater on the smaller ship and resort has often to be made to a smaller active length of aerial wire. It has not been uncommon with a transmitter of 500 watts and a main aerial length of 200ft to obtain with a receiving aerial of 100ft about 50 volts of r.f. across the 75-Ω coaxial cable termination. From statistics available this high voltage is to be found at transmitting frequencies somewhere in the region of 6 Mc/s. Length of aerial and spacing will modify this resonance considerably. At other frequencies usually less than 1 volt will be induced for the same transmitted power. No amplifier can handle 50 volts of input, and in practice a limit of about 25 volts would be set, adjusting aerial length or position to keep the "resonant" voltage down.

TABLE I.

MARINE TRANSMITTING BANDS	
415 —525 kc/s	M.F. Band
1.6 —3.8 Mc/s	I.F. Band
4.063—4.238 "	H.F. Band
6.20 —6.357 "	"
8.195 —8.476 "	"
12.33 —12.714 "	"
16.46 —16.952 "	"
22.00 —22.400 "	"

Some means of rejecting the transmitting frequencies has to be adopted and a standard form of filter was used. Assuming the worst case of 25 volts on the aerial coaxial lead-in cable and a minimum filter attenuation of 36 dB, the amplifier must handle 0.4 volt. From Table I it will be appreciated that

* Formerly with the Marconi International Marine Communication Company Limited.

considerable band filtering would be required. It was decided that the standard amplifier should incorporate two band-stop filters covering the M.F. and I.F. bands only. In regions of dense shipping, transmissions in these two bands from ships close by can give rise to a total r.f. voltage on the aerial of as much as 50 mV. A filter unit for the H.F. bands used by the ship's transmitter would be separate and would be an optional extra. Where H.F. band transmissions are likely to be few in comparison with those in other bands, such a filter unit could be saved by using a remotely controlled relay to disconnect the aerial completely in order to keep high voltages out of the amplifier input during periods of transmissions in the H.F. bands.

To cover all the broadcast bands, the amplifier should possess a sensibly flat frequency response between 150 kc/s and 25 Mc/s. The input impedance to suit the aerial coaxial cable should be 75Ω and the outputs also suitable for feeding into 75Ω coaxial cables. The method of distribution is shown in Fig. 1, from which it is evident that although the loading, and consequent slight mis-match at each outlet point, is quite small a large number of receiver outlets could load the cable and introduce a cabling loss. The input impedance of each receiver differs considerably at any one frequency according to the tuning of the receiver and consequently the summation of all the loading effects is modified. It was decided to cater for up to 20 outlets and that four amplifier outlets would give a good economic compromise. In standardizing on equipment the circuit complexity and reliability have to be weighed against the average demands. In isolated cases, as indicated by present market demands, a ship requiring more than 80 outlets could be covered with two or more amplifiers working in parallel.

The amplification required was fixed at approximately 15 dB. As will be evident later, this again was a compromise between producing voltages at the receiver outlet points identical with that on the aerial terminated with 75Ω and keeping spurious responses within the amplifier to a minimum. In practice the overall gain of the system between aerial and the input terminals of the receiver also takes into account the fact that the aerial fitted for the distribution system will have a greater effective height than the average length of wire that can be slung haphazardly. Thus the equivalence of voltages at aerial and receiver can be disregarded. Emphasis was laid on making available in the cabin a "clean" signal free from machine noise interference, spurious responses, etc.

Effects of Amplifier Non-linearity.—The term a "linear amplifier" is, of course, only relative, but it does imply that in addition to producing an amplifier with a wide-band response attention has also been paid to obtaining the maximum degree of linearity. The wide-band amplifier suffers from the inherent disadvantage that in amplifying many signals simultaneously any non-linearity will produce other signals at the output. A power series can be used to represent the "curvature" and is in the familiar form $ax + bx^2 + cx^3$. This is equivalent to saying that the amplifier is capable of producing, as in audio techniques, the second and third harmonics of a fundamental sine-wave input. The two input signals are represented by $p \sin \alpha$ and $q \sin \beta$, and where one is considered to be modulated, p becomes $p(1 + m)$ where $m \gtrless \pm 1$. Analysis shows that the first term can be neglected, but the second term produces the expression $b\,p\,q$ $[\cos(\alpha - \beta)t - \cos(\alpha + \beta)t]$. Thus the original carriers α and β have produced spurious carriers $(\alpha - \beta)$ and $(\alpha + \beta)$ both of which are dependent on the product $p\,q$. This means that modulation of either original carrier will produce modulation of the spurious carriers. This is called inter modulation (I.M.).

The third term produces the expressions $3c\,p^2\,q$ $[\sin \beta\ t - \frac{1}{4}\sin(2d + \beta)t + \frac{1}{4}\sin(2\alpha - \beta)t]$ and $3c\,p\,q^2$ $[\sin \alpha\ t - \frac{1}{4}\sin(\alpha + 2\beta)t - \frac{1}{4}\sin(\alpha - 2\beta)t]$. The second and third terms in each of the brackets are similar to the I.M. terms discussed above except that the spurious responses are at different frequencies and that the spurious carrier modulation is proportional linearly to one original carrier and to the square of the other. This would mean that for low levels of original modulation the spurious carrier modulation would be double that for modulation of either p^2 or q^2 compared with modulation of p or q. Thus if p carrier is modulated the spurious carrier modulations at $(2\alpha + \beta)$ and $(2\alpha - \beta)$ will be double that at $(\alpha + 2\beta)$ and $(2\beta - \alpha)$. For modulation levels over 50%, severe distortion will be present in the spurious modulation of the first two frequencies. To discriminate between the two forms of inter modulation caused by the b and c coefficients in the power series expression, they will be called first-order intermodulation (1st I.M.) and second-order intermodulation (2nd I.M.) respectively.

The first parts of the third term expressions show that the original frequencies α and β are being produced, but whereas the modulation of carrier α was represented by an amplitude variation of p, this spurious response, at the same frequency, has

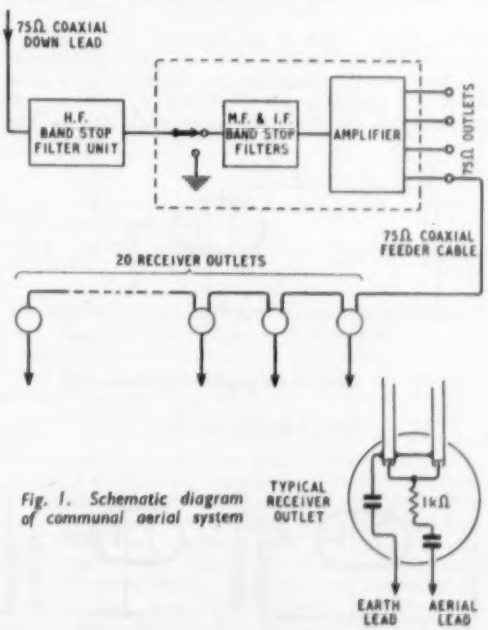


Fig. 1. Schematic diagram of communal aerial system

a modulation proportional to q^2. Thus the modulation of one carrier has become superimposed on the other. This effect is known as cross-modulation (X.M.). In this instance the unwanted effect will not be measured as the amplitude of an unwanted carrier, that would be coincident with a true carrier signal, but as the amount of background modulation existing on a true carrier having its own modulation.

In order to assess the linearity of an amplifier for this application, a limit on the unwanted responses enumerated above has to be set and a criterion based on the interpretation of test results has to be laid down. These matters will be referred to later.

Calculations have shown that in terms of the ultimate performance criteria laid down for I.M. products, the amplifier linearity is such that at the maximum voltage levels concerned, the 2nd harmonic production would be 0.0025% and for the 3rd harmonic 0.0004%. Although these figures are theoretical, they give some idea of the order of linearity required. Adoption of negative feedback methods would entail a considerable amount of feedback over the amplifier which, coupled with satisfying the Nyquist stability criterion over a very wide band, would be extremely difficult. The use of large valves working over a small portion of their characteristics would be most uneconomic if taken to the stage where linearity could be considered acceptable.

Current Amplification.—The amplifier circuit finally developed is actually one that amplifies the input current although to all intents and purposes it may look like a variation of a voltage amplifier.

The basic amplifier circuit is that of the grounded grid triode, as shown in Fig. 2. The input impedance at the cathode is $R_c' = \frac{r_a + R_L}{1 + \mu}$. Now if $R_L \ll r_a$, R_c' becomes $\frac{r_a}{1 + \mu}$ or approximately $1/g_m$ for a high-μ value. Now if the cathode is fed from a constant-current source ($Z = \infty$) any non-linearity of the $I_a - V_g$ characteristic resulting in a non-linear R_c', will have no effect and V_o will be truly proportional to the input current. If now the impedance R_c' is presented to a valve, as in Fig. 3, and the impedance presented to the first triode is low compared with its r_a, then there is a good approximation to a constant-current feed. If V1 were a pentode, the approximation would be very good, but for reasons to be discussed later the pentode must be discounted. Further still, if the impedance in the cathode of V2 is high, the effective output impedance of V2 will become $r_a + (1 + \mu)R_c$, where R_c is the impedance in the cathode. If, say, for V2 the anode load to V1 is $r_a/10$, then the output impedance of V2 becomes $r_a + (1 + \mu)\frac{10r_a}{(1 + \mu)} = 11r_a$

The effect of R_c in V1 and the anode load in V2 is neglected for simplification. It should be noted that as the cathode and anode currents are one and the same thing in each valve, the amplification, as such, takes place in each transformer which serves to step up the current between valves. The amplification being substantially independent of the valve parameters, stability of h.t. and heater volts is unimportant; nor is the amount of h.t. ripple voltage, within reason, of any great importance. In the final circuit (Fig. 4) it was decided to use a push-pull arrangement because (a) greater linearity would be expected, (b) the circuit would be inherently more free from extraneous noise pick-up (i.e. mains borne interference), (c) it could provide means of adjusting the "balance" of the circuit and thus permit of some correction of dissimilar valves, and (d) the impedance presented to a previous stage would be held more constant.

As already mentioned, the pentode would appear to offer a very good approximation to a constant current source and might successfully be used as a grounded-grid amplifier in preference to the triode. Used in that manner the cathode current would be the sum of the screen and anode currents and any input current would be divided between screen and anode. In addition to reducing the current gain in the circuit (the screen circuit acting as a partial current bypass) the output current at the anode would no longer be truly proportional to the input current. Inspection of valve characteristic curves shows that the ratio of anode current to screen current is not constant for variations of grid-to-cathode potential and non-linearity would obviously be present.

Linearization Factor.—This term has been introduced as a way of expressing the capability of the circuit in reducing non-linearity of the valves. In Fig. 2, a generator of internal impedance Z is used to feed a current into the non-linear impedance R_c'. The greater Z compared with R_c', the smaller the effect of variation in R_c' will be on the relationship between I and E. The linearization factor is defined as $\frac{Z + R_c'}{R_c'}$ and if $Z = 9\,R_c'$ we can expect harmonic distortion products to be reduced by 10.

Circuit Considerations.—From the point of view of economy, the four 75-Ω outputs were arranged to be fed from one output stage. Only one output

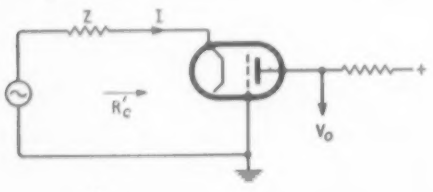
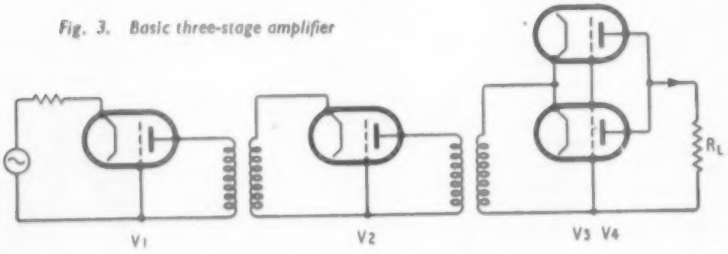


Fig. 2. Triode in the grounded-grid connection

Fig. 3. Basic three-stage amplifier



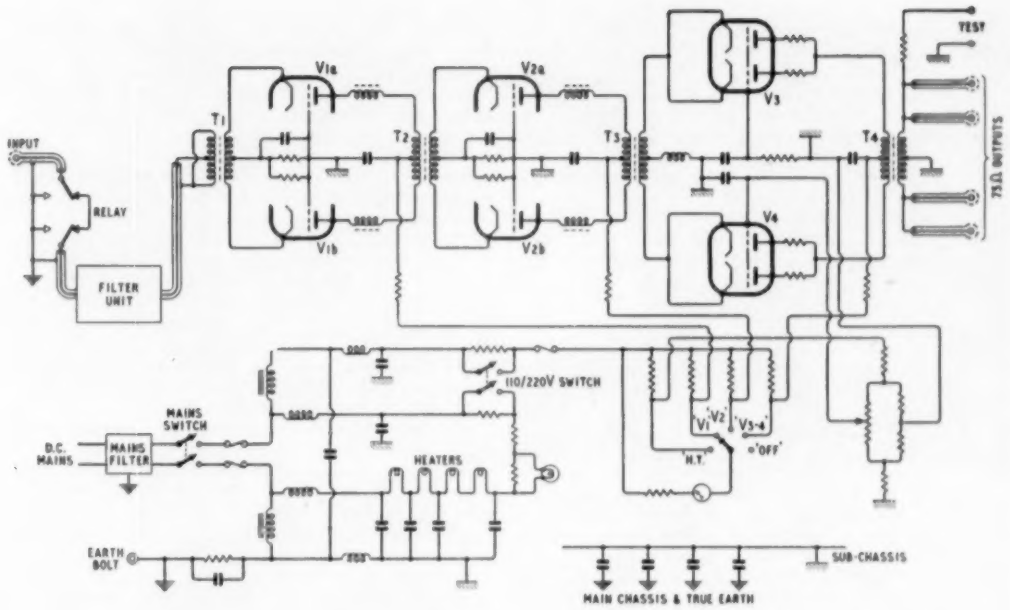


Fig. 4. Complete circuit diagram of final design

transformer was therefore required, but to obtain sufficient power gain in the last stage, a parallel push-pull arrangement of valves was adopted. Actually this meant a lower effective load impedance on the secondary of T3 and consequently a higher current amplification in the transformer could be obtained. This practice of paralleling valves to obtain greater current amplification by the preceding transformer cannot be carried out indefinitely owing to other limitations due to circuit capacities. The use of PCC84 valves enabled the whole amplifier to be constructed using four valves, which permitted the chassis to be packed in a very small space.

The success of the amplifier largely depended on the r.f. transformers which should have (a) good frequency response, (b) an effective high shunt loss impedance, and (c) freedom from non-linear hysteresis losses. An obvious choice of core material was Ferroxcube which proved to be very satisfactory. Shunt capacities across transformer primaries will serve as a current bypass at the anode of each valve with the result that at high frequencies the amplifier gain will be reduced. This effect sets an upper limit to the reflected primary impedances and, consequently, the turns ratio. From this basic consideration the gain per stage can be derived for the type of valve in question, and finally, the overall gain of the amplifier, which was calculated to be 15.2 dB.

It will be realized that shunt losses on the transformers will serve to bypass some of the current fed from the preceding valve with the result that the " constancy " of the current feed is impaired and the linearization factor will suffer. Alternatively, the impedance feeding the following valve is lowered. It is interesting to note that the linearization factor for the output stage, calculated for the valves alone, was 72.5. The transformers do not permit this figure to be fully realized in practice, but it indicates the measure of linearization that takes place.

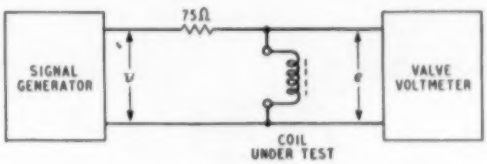


Fig. 5. Test circuit for effective shunt loss impedance

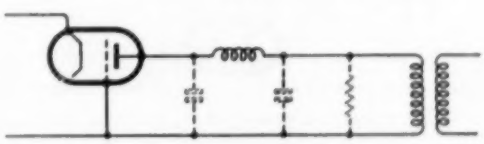


Fig. 6. Use of inductance to improve the gain at high frequencies

To assess the effective shunt loss impedance caused by core losses, a test circuit as shown in Fig. 5 was set up. Tests on various core and windings were carried out by measuring the change of voltage across the test terminals when the coil was connected in parallel. Shunt losses are of no particular consequence in T1 and T4 as they do not reduce the linearization factor by bypassing current fed into the cathode of a following amplifier. The shunt losses were found to be remarkably constant up to 30 Mc/s. In order to reduce the effects of winding capacities, which would be in parallel with the shunt losses, no secondary was coupled to the test winding.

When winding the transformers, care was taken to ensure a high coupling coefficient. Frequency response tests showed that up to 25 Mc/s, under

conditions that were not as favourable as those in the valve circuit, the responses were within ± 1dB of the 1 Mc/s response.

As already mentioned, shunt capacities will cause loss of gain at high frequencies and to mitigate this compensating coils were introduced in the second stage. Fig. 6 shows the circuit capacities between which a coil of a few microhenries can give a useful "lift" up to 25 Mc/s.

The balance control in the grids of the output valves provides a differential bias voltage of ± 0.2 volt which was found adequate to deal with all normal dissimilarities between valves.

Amplifier Details

It was found on test that the signal-handling capacity of the amplifier was improved by introducing a high impedance into the common cathode connection. This results in the two cathode input impedances on each side of the circuit being in series instead of effectively in parallel. To explain the beneficial action of the choke, consider Fig. 7(a) in which a transformer is shown with series loss resistances across which must be developed a voltage proportional to the input current of the valve. Any non-linearity of R_c' will produce harmonic voltage components e_1 and e_2 across r_1 and r_2. From the point of view of even harmonics, if the valves were indentical e_1 would cancel e_2, but with dissimilar valves a difference voltage would exist. Now with the secondary centre tap earthed, a difference voltage $(e_1—e_2)$ acting in one cathode will effectively be applied between the cathodes (Fig. 7(b)), and will cause a current to circulate round the push-pull circuit. With a high impedance to earth from the centre tap, the resistances can be considered as being in series with the constant-current source on the primary side and will have no effect other than to cause half the difference voltage $(e_1—e_2)$ to appear across the choke. Although conclusive proof of this explanation, as to the advantageous effect of the choke, has yet to be established, the practice appears to be sound. The introduction of 10Ω into one cathode, for instance, was found to reduce considerably the signal handling capacity where 2nd harmonic distortion products were concerned.

The meter circuit enables the valve currents and the h.t. to be monitored, while various dropper resistances serve to reduce the voltages when working on 220 volt d.c. mains. The total consumption from the mains on 220 volts was 82 VA.

The amplifier was constructed as a small sub-chassis and mounted at the four corners by four v.h.f. type, bush-mounted, mica condensers. The amount of chassis work at d.c. mains potential was considerably reduced, while at the same time a satisfactory r.f. bypass to the main chassis at true earth potential was ensured. In addition to the r.f. chokes, a standard all-wave mains filter was incorporated to reduce the likelihood of mains-borne interference reaching the amplifier. The sub-chassis, measured overall, was 10½in. long, 6in wide and 4in deep. The greater part of the main chassis and space within the case was taken up with components associated with supply circuit and filtering arrangements.

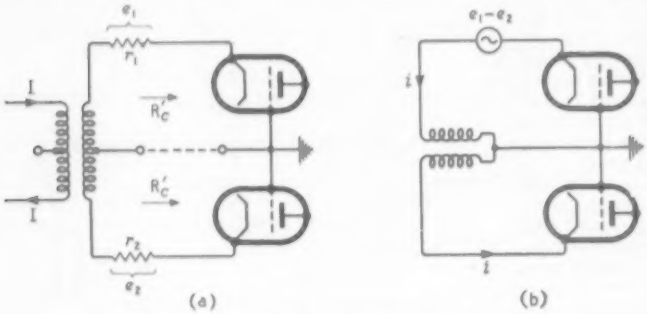
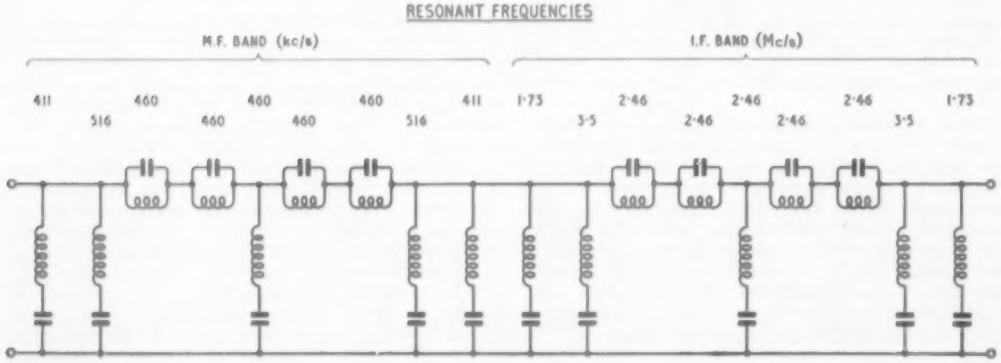


Fig. 7. Explaining the action of the cathode choke

The r.f. double band-stop filter circuit in Fig. 8 is conventional, each half consisting of a full constant-k section bounded by two half m-derived sections, having $m = 0.6$. Each band-stop filter has nine coils, a number which it was not possible to reduce, owing to the necessity of having to maintain a certain minimum attenuation between the resonant peaks. By judiciously laying out the filter to reduce magnetic coupling between the dust-iron cores to negligible proportions the filter was constructed within a box measuring 10in × 4in × 2in high.

(To be concluded.)

Fig. 8. Outline of double band-stop filter



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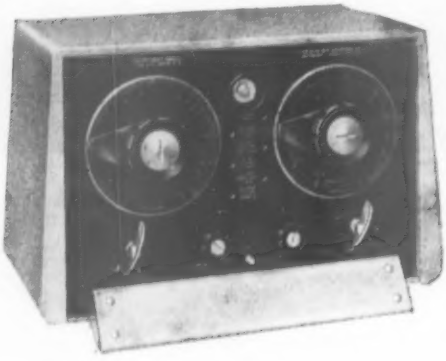

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Broadcasting in the U.S.S.R.

FROM A CORRESPONDENT

IN the Soviet Union, broadcasting is primarily the responsibility of the Ministry of Culture. This is the programme body; its transmitting equipment and engineering staff is provided by the Ministry of Communications for which, in turn, much of the technical development work is done by the Ministry of Radio Engineering.

The internal sound service radiates three programmes. The first is of mixed material, rather like our Home Service; the second is essentially artistic, with music and literature mixed, while the third is all music, with no talks. Some 85-90% of all material radiated is from recordings, so studios are provided accordingly; in this respect there is a marked difference between Russian and British practice. Ribbon, moving-coil and condenser microphones are used, depending on the nature of the programme material being recorded or broadcast.

Another difference is to be found in the choice of wavelengths for the internal sound services. Due to the vast distances to be covered, extensive use is made of short waves. Long waves are used for intermediate ranges, while medium-wave transmitters cover the main cities and the areas surrounding them.

A typical medium-wave transmitter is rated at 100 kW, and feeds a mast radiator slightly over 500 ft in height. High-level Class B anode modulation is employed with 20 dB negative feedback. A long-term frequency stability of ± 3 c/s is claimed; harmonic distortion at 95% modulation is given as 2%. Overall efficiency is 35%.

The short-wave transmitting centre, about 40 kilometres from Moscow, is something quite exceptional, combining as it does more or less the functions of our own Daventry and Rugby stations rolled into one. There are at present eight high-power broadcasting transmitters (80-120 kW) and twenty-five medium-power transmitters (15-50 kW) for telegraph and telephone traffic. The site, which covers 2,000 acres, provides space for 36 aerial arrays for broadcasting and about 60 rhombic aerials mainly for telegraphy and telephony, though some are used for broadcasting. The transmitter buildings, together with the houses and flats for the staff, make up something more like a town than a radio station. Shops, a school and a bank are all on the site.

A typical high-power short-wave transmitter has five r.f. stages, all being push-pull except the first. The last two stages use water-cooled valves, only the final being earthed-grid. The modulator, working in Class B, has four stages of amplification, with water cooling in the last two. Transmitter-to-aerial switching is largely remotely controlled, though there is still a certain amount of manual switching.

SOME DETAILS OF THE SOUND AND VISION SERVICES

Energetic steps are being taken in the U.S.S.R. to build up a frequency-modulated v.h.f. service, though few transmitters are as yet in operation. The incorporation of sound broadcasting channels in television receivers is being encouraged: the transmission characteristics for both services are identical. V.H.F. broadcasting is being introduced because of congestion on other bands and to allow regional areas to be served with signals of better quality.

Generally speaking, v.h.f. stations are of rather lower power than those operated by the B.B.C. Most are of 5 kW, with aerial gains of between 5 and 10. These stations are said to give good reception up to 60 km and tolerable signals up to 120 km, depending on the terrain. The transmitters work on frequencies just above our Band I; frequency spacing between transmitters on the same site is 2.25 Mc/s. Contrary to the practice in this country, v.h.f. sound broadcasting aerials are not mounted on the television masts: this is thought likely to give trouble from interaction between the two transmissions.

For feeding all these stations there is an extensive network of high-quality landlines between Moscow and the various main cities of the Soviet Union. Screened pairs are generally used for distances up to 4,000 km, but plans are being made to change over to the use of two or three channels of the co-axial or screened pair carrier systems. To lighten the load on the lines, tape recordings are often sent to distant cities.

As already stated, recordings are more widely used than here. Magnetic tape is almost universal; the advantage offered by discs for taking rapid excerpts is considered unimportant and the quality obtainable from tapes has been a deciding factor. All the Soviet recording and reproducing equipment now follows the C.C.I.R. standards.

Three types of tape recorder are used: studio, two-channel mobile and midget portable. The studio machines run at either 15 or 30 inches per second, the slower speed being generally used. The mobile equipment, installed in a 30-cwt van which serves as a small studio, runs at 15 in/sec. Midget recorders (7½ in/sec) are now being manufactured in large numbers for use in news reporting or on-the-spot commentaries.

In studio work it is usual to record the master tape with a dynamic range of the order of 56 dB and the producer has seldom to adjust his volume control. This wide-range master tape is then used to make a tape for broadcasting, "dubbed" down to the required 22 dB dynamic range. The Soviet librarians have not encountered any difficulties over deterioration of master tapes, which are stored at a temperature of 15°C and a humidity of 50-60%.

Wired distribution plays an important part in Soviet broadcasting in the big cities. Out of a total of 35 million sound licences, some 25 million are "on the relay" though a number of these use radio reception as well.

The type of receiver to be supplied to the public is decided mainly by the Ministry of Communications after discussion with the Ministry of Radio Engineering. Roughly speaking, sets cost the same as in England, but without the purchase tax. Transistors are not in general use for domestic purposes, but it is considered important that their application should be developed rapidly, as many listeners still have no mains supplies.

Television in the Soviet Union began to develop rapidly only during the last year or two. At present there are 15 "centres"; this number will be increased to 75 during the next five-year plan, ending in 1961. A television centre comprises a transmitter and a source of programmes—studios, film scanners, O.B. units, etc., depending in extent and number on the importance of the centre.

In the principal cities the hours of transmission are from 7 p.m. to 11 p.m. every day, except Thursdays, when the stations close down for maintenance work. Extra transmissions are radiated during public holidays and broadcasts of topical events are made at various times outside the normal programme hours.

The system corresponds very closely on the video side to the C.C.I.R. 625-line standards.* Stations operate on the frequencies set out in the accompanying table. Radiation is horizontally polarized. The sound transmission is frequency modulated with a deviation of 75 kc/s.

Channel	Band Limits (Mc/s)	Vision Carrier Frequency (Mc/s)	Sound Carrier Frequency (Mc/s)
1	48.5–56.5	49.75	56.25
2	58 –66	59.25	65.75
†	66 –73	—	—
3	76 –84	77.25	83.75
4	84 –92	85.25	91.75
5	92 –100	93.25	99.75

†V.H.F. sound broadcasting

The main Moscow transmitter (there is also a low-power experimental station) has a peak power of 15 kW and an aerial gain of the order of 3. Allowing for feeder losses this means that the e.r.p. is about 40 kW. The accompanying sound transmitter is stated also to have a power of 15 kW. High-power modulation is used in the vision transmitter and all the high-powered valves are water cooled in both vision and sound transmitters.

Television transmitting aerials are of the bat-wing type with three such aerials stacked one above the other. These aerials are carried by self-supporting towers of about 500 ft in height. The most-recently built mast (at Kiev) is of unconventional design, being made up of tubular members which provide an economical, effective and very good-looking structure.

At a range of 70 miles these main stations are said to provide a field strength of the order of 200 μV/m which produces a satisfactory picture on the ordinary Soviet receiver when used with a receiving aerial having one reflector and one director. But a field strength of 500 μV/m is considered necessary for a first-class picture when using such a three-element receiving aerial. Much of the land around Moscow is almost flat so the transmitter has a not-too-difficult job in putting down a satisfactory signal at the edge of the service area.

In the 1,500-sq ft studio of the Moscow television centre 5 cameras are installed, all with image iconoscope tubes. Electronic viewfinders with 5-in tubes are in general use in the Soviet equipment. The film scanners at Moscow are 35-mm machines, optically multiplexed on two iconoscope-type cameras. Each machine has its own associated optical sound head. Two transparency scanners, each with its own iconoscope camera, are used for producing test cards and captions. This equipment is shortly to be replaced by new gear using image iconoscopes.

In the Soviet image iconoscope the cylindrical part of the envelope containing the mosaic is about 5 in in diameter. The mosaic is about 3 in × 2¼ in and the photo-cathode is 1¼ in in diameter. It has a short scanning gun with an external neck diameter a little less than 1 in; overall length of the tube is about 9 in.

In Moscow there are two outside broadcast units of Soviet manufacture. Each of these consists of two vehicles adapted from standard omnibuses. In one vehicle is housed the camera control unit producer's desk and switching system, picture monitors and power supplies. The other vehicle contains the sound equipment only, the rest of the space being available for carrying cameras, radio link equipment and cables, etc. The O.B. cameras employ image orthicon tubes of Soviet manufacture. The camera itself is compact, measuring, with viewfinder, 12 × 12 × 20 in. Weight, without lenses, is about 100 lb.

The latest type of radio link used for O.B. work operates on 300 Mc/s and employs frequency modulation. A klystron in the output stage delivers 100 mW with a frequency deviation of 1.5 Mc/s to a dish aerial of about 5-ft diameter. This equipment is stated to give a useful range of about 13 miles. The sound channel works on the same carrier frequency, but the aerial polarization is at right angles to that of the vision aerial.

With the exception of a temporary co-axial cable between Moscow and Kalinin (140 km), there is at present no system for linking together the various stations. Some 6,000 miles of two-way link, partly radio and partly cable, is due to be provided during the course of the present five-year plan.

Television receivers on sale in the shops employ 7-in, 14-in and 17-in tubes. It is stated the 7-in set is no longer in production, but at present the majority of sets have that size of tube. The prices of the sets in Moscow are, respectively, 1,275, 1,900 and 2,300 roubles. To give a basis for comparison with our own receiver costs, it may be said that a skilled workman earns about 2,000 roubles a month, while the basic worker's wage is 800 to 1,000 roubles.

Most observers agree the Soviet receivers provide a most excellent interlace, but, judging by brightness and contrast of the picture, the tubes are not aluminized or else the e.h.t. is rather low. The general policy on future television receiver design at present seems to provide for the inclusion of three v.h.f. sound channels.

* Details are given in the Appendix.

Domestic receiving aerials are very much as in Britain, except for the difference in polarization. Near the transmitters simple dipoles are used, and as one goes farther towards the limits of the service areas the aerials become more complex.

For domestic power supply the Soviet Union has adopted 220 volts, 50 c/s. But at present there are large areas, including most of Moscow, on 127 volts. For this reason it is not possible to standardize television receivers with series-connected valve heaters. This has, in turn, had some influence on valve design. Most of the valves used in domestic receivers are octals based on the American types. A series of miniature valves based on the Philips "E" series is also in production. Germanium diodes are to be used for rectifying anode supplies in the new television and sound receivers becoming available to the public later this year.

The number of television receivers in use in the Moscow area is given as 600,000 to 700,000; in Leningrad 100,000 and in Kiev about 70,000. It is expected that by the end of the five-year plan there will be a total of 40 million. The annual licence fee for a television receiver is 120 roubles, for a sound broadcast set 36 roubles and for connection to the wired relay system 60 roubles (which does not include the loudspeaker).

Transmissions from film and outside broadcasts take up more of the Soviet television programme time than here; more than half of the time seems to be occupied by films. That explains why the studio space is relatively small.

So far as colour television is concerned, the experimental frame sequential system has been abandoned and development work has begun on a 625-line simultaneous colour system. Experimental transmissions are expected to begin in about two years' time; a regular service might start within the period of the present five-year plan. It is thought possible that, unless the C.C.I.R. come to a quick decision on a standardized colour system for Europe, the Soviet Union might well work on independent lines, introducing the system thought best for their needs. Transmissions would probably be on frequencies corresponding to our Band III.

Television is being given high priority in the next five-year plan, with the emphasis on getting a service into the homes of the people without too many technical "frills." There can be no doubt that Soviet research workers, development engineers, manufacturers and technicians will be able to produce and operate the gear needed to fulfil the plan.

APPENDIX

Soviet Television Standards

THE width of the line synchronizing pulse is 8% of the total line time (approximately 65 microseconds); the front porch is 2% and the total line blanking period 12½% of the line time. The frame synchronizing signal consists of five equalizing pulses followed by five broad pulses, which in turn are followed by fifteen equalizing pulses giving a total frame blanking of 12½ lines (the exact number of these pulses cannot be guaranteed). The transmitted picture/sync ratio is 75:25, the picture modulation being negative going. The radio-frequency bandwidth is 8 Mc/s. The spacing between sound and vision carriers is 6.5 Mc/s, giving a video bandwidth of approximately 6 Mc/s.

Battery-driven Record Player

IT is estimated that 1,500 sides of 7-in, 45-r.p.m. records can be played at a cost of 2s 4d for four standard U2 cells on the "Transistor" record player recently introduced by Philco. A pull-pull output is provided in the three-stage transistor amplifier which is built by the printed circuit technique, and the motor-driven turntable and pickup is of Garrard design and manufacture. The motor switch is incorporated in the pickup arm and is operated when the arm is moved to and from its rest position.

Storage space is provided for up to 16 records in their covers or 24 without covers. There are three controls; namely, volume, motor voltage compensation and circuit function, the last with the following four choices.

A. Normal record reproduction, either from the built-in pickup and turntable or, through sockets at the rear, from an external pickup and turntable for, say, existing 78 r.p.m. records.

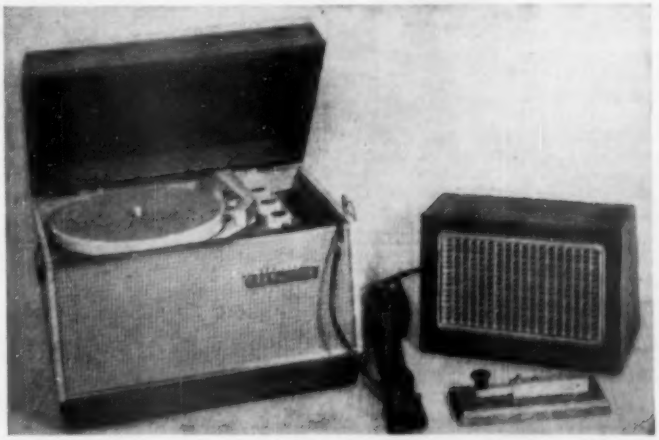
B. Morse practice oscillator, with key connected to the sockets.

C. With a microphone "speech unit" connected to the input sockets the amplifier and loudspeaker can be used as a "baby alarm."

Under quiescent conditions the standby current is only of the order of 5 mA.

D. The internal loudspeaker acts as a microphone and the "speech unit" is used as an extension loudspeaker for an "intercomm." system. By returning the switch to position C for the reply, a two-way conversation is possible.

The price of the Philco "Transistor" excluding batteries and accessories is £26 5s, inclusive of purchase tax.



Philco "Transistor" combined battery portable gramophone, Morse practice set and "intercomm." system.

Electronic Machine-Tool Control

SYSTEMS NOW FINDING THEIR WAY INTO INDUSTRY

Fig. 1. Electronic positioning equipment by Mullard applied to a Coventry Gauge and Tool jig boring machine. The row of signal lights are situated at the top of the control console.

WHAT is generally meant by electronic machine-tool control is the control of operations such as drilling, turning or milling by numerical information supplied by magnetic or paper tape, punched cards, or hand settings on control knobs. In this respect it is distinct from copying methods in which the machining information comes from jigs or templates taking the actual form of the work to be reproduced (although it must be admitted that many copying systems do, in fact, employ electronics).

The main purpose of this numerical control, like many other such techniques in the field of "automation," is to save expensive man-hours of human labour. But it is applicable only when small quantities of parts are to be machined. In large-scale production it is worth while making expensive jigs and templates because their cost is shared out between a great number of parts reproduced by semi-skilled labour and adds very little to the cost of each one of them. With small-quantity production, however, the use of jigs becomes uneconomic, especially if precision work is being done. The other alternative, of using a skilled machinist to turn out the small number of parts individually, is also expensive and time consuming.

Numerical control, on the other hand, requires neither jigs nor skilled craftsmen. It certainly involves an extra process—that of translating the spatial information from the drawing-board into numerical control signals—but the time taken for this is quite short compared with the slow, head-scratching progress inseparable from careful craftsmanship. And once the translation is done the electronic control system will carry the job straight through with the maximum speed at which the machine tool is capable of operating.

Fig. 2. B.T.-H. position control system used on a Kearns horizontal boring machine.

Positioning Methods

Most of the control systems in use have already been described in *Wireless World* but on the occasion of the recent International Machine Tool Exhibition it was possible to see all of them together, in their latest stages of development, and to get an impression of how they are actually being applied in the machine-tool industry. Several methods of control were to be seen in operation and these could be divided into two distinct groups: discrete position control (bringing the work to a series of fixed positions for operations like drilling), and continuous position control (moving the work continuously past a cutting-tool for processes like milling).

Taking discrete position control first, here the work-table has to be moved in two dimensions under the control of numerical information on the x and y co-ordinates of, say, the hole to be drilled. When the required point is under the drilling bit the work-table stops. In most systems this is done by a form of servo-mechanism. For each co-ordinate, the distance to be moved by the work-table is set up manually in digital form on a series of control knobs which produce an error signal, either in electrical or mechanical form. The appropriate lead-screw of the work-table is driven by an electric motor and at the same time the distance moved is measured by an electro-mechanical or electro-optical device. This device

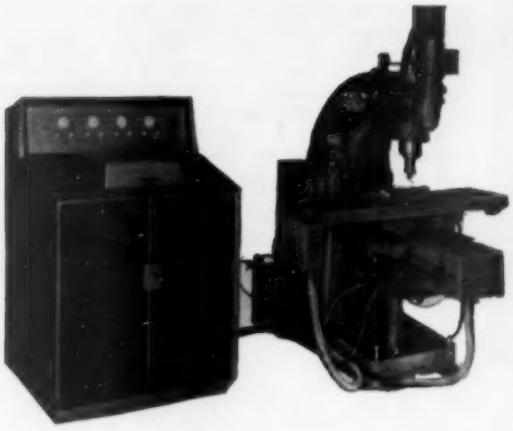


Fig. 3. Ferranti equipment for controlling a Kearney and Trecker milling machine. The magnetic tape is "played back" in a compartment on the top of the control console.

generates a corresponding signal which is arranged to cancel the original error signal. When the cancellation is complete—that is, when the work-table has moved the distance specified by the error signal—the driving motor is stopped.

For example, in the Ferranti system (displayed on their own stand at the exhibition) the required dimension, or error signal, is established by the initial positions of the glow discharges in a series of Dekatron tubes forming an electronic counter. The work-table movement is measured by an electro-optical interference-pattern system which produces a pulse for each ten-thousandth of an inch of displacement, and these pulses cancel the number set up on the Dekatrons by causing the initial glow discharges to move backwards step by step to zero. The system has been described fully in our January, 1955, issue.

Another system using an electronic counter and an electro-optical displacement measuring device has been developed by Mullard and was shown at the exhibition controlling a jig boring machine on the stand of the Coventry Gauge & Tool Company (see Fig. 1). Here, however, the equipment has not yet reached the stage of fully automatic positioning. When the error signal is reduced to zero a lamp lights up and an operator has to press a button to stop the work-table drive. The optical measuring system (also described in the January, 1955, issue) makes use of a scale of alternate opaque and transparent bars, an image of which emerges from behind a vertical edge as the work-table moves. The number of bars revealed (representing displacement) is then counted by means of a flying-line scanner and photocell arrangement.

The required dimension for each ordinate is set up by a series of 10-position dials on an electronic counter (of the four-stage binary type, with feedback). Pulses from the photocell are fed to the counter which, at the end of each scan of the flying line, registers the difference between the number set up on the dials and the actual distance (in ten-thousandths of an inch) which the work-table has moved. The output from the counter then passes through a matrix circuit to a series of cold-cathode trigger tubes which are used to switch on indicating lamps.

The purpose of the matrix circuit is to break down the difference or error numbers into groups. Thus, if the error is 100 ten-thousandths or more one of the lamps lights. If between 50 and 99 units the adjacent lamp lights, and so on in steps of decreasing size, until, as the correct setting is approached, indication is given in steps of one ten-thousandth. The error is in fact displayed on a row of 17 lamps, with the centre one for zero and the end ones for an error of 100 or more ten-thousandths in either direction.

In the B.T.-H. system of discrete position control (shown operating on boring machines by H. W. Kearns and Company, see Fig. 2, and The Newall Engineering Company) a magnetic system is used for the distance measurement on the work-table. For each direction of motion the scale consists of a bar of magnetic material (fixed to the work-table) with a series of holes bored at exactly one-inch centres and filled with non-magnetic material. As the work-table moves this bar varies the flux in a differential pick-up head mounted (but movable) on the fixed part of the machine. The coils of the head are connected to an electronic circuit which detects the difference of flux in the two magnetic paths, and this difference is amplified and used to control the servo motor driving the lead-screw so that the difference is reduced to zero. As a result the measuring bar becomes automatically positioned with one of its filled holes in exact alignment with the pick-up head.

Two-stage Positioning

It is, in fact, the initial placing of the pick-up head relative to the bar which provides the error signal on which the system partly depends. The required dimension is actually set up manually on six dials as a row of digits, for example 11.3054. The four dials corresponding to the "decimal" portion of the dimension operate a system of synchros and a servomechanism which positions the pick-up head in accordance with that part of the dimension. The two dials displaying the "integer" portion of the dimension, however, operate another synchro system which controls the lead-screw drive until the work-table is within $\frac{1}{2}$in of its correct position. Control of the drive is then transferred to the differential pick-up head, which operates as described above. Positioning is completed when the poles of the pick-up head are symmetrically placed relative to the nearest hole in the scale bar.

Incidentally, the initial setting-up of dimensions on this B.T.-H. equipment can also be done from information on punched cards. A mechanical card-reading device senses the positions of the holes in the cards and automatically positions the setting dials by means of a clutch and detent mechanism. The two sets of co-ordinates are fed in simultaneously.

While the accuracy of the measuring devices used in all the above systems is as high as 0.0001 inch, the overall accuracy of the positioning depends on a number of factors and may be somewhat less. In all cases, however, it is appreciably better than half a thou' which is quite sufficient for most engineering purposes.

Compared with discrete position control the con-

Fig. 4. The digital computer used with the Ferranti system. The input paper tape can be seen on the left and the magnetic tape recording the output signals on the right.

tinuous position control systems are a great deal more complicated. Here the general principle for, say, milling a piece of metal to a certain contour is that the numerical input information provides sets of co-ordinates of marker points defining the contour while a computer interpolates the points between in suitable curves.

In the Ferranti system (demonstrated on their stand, see Fig. 3) the information taken from the original drawing consists of co-ordinates of points of change on the contour and specifications of the types of curves between them. With a semi-circular part of the contour, for example, it is necessary to have the co-ordinates of the points where the semi-circle begins and ends and the co-ordinates of its centre point. This kind of information is put on to a planning sheet, then punched into a paper tape in the form of a code pattern of holes.

The punched tape is fed into a digital computer (see Fig. 4) and the information is "read" group by group by the machine, which has circuits for "recognizing" the dimensions and the instructions for particular curves as they appear. The output of the computer consists of two sets of pulses recorded on magnetic tape which constitute command signals to the two lead-screw drives of the machine tool. These pulses specify completely the contour to be cut in terms of increments of distance in two directions from a given reference point. Each pulse represents a work-table movement of 0.0001 inch and the density of the x-direction pulses relative to the y-direction pulses is indicative of the type of curve which is being traced.

Overall Accuracy

The completed magnetic tape carrying the command pulses is then played back into the electronic control mechanism of the milling machine. The method of control (described in our January, 1955, issue) involves a servomechanism in which the work-table driving motor is stopped every time a pulse from the interference-pattern displacement-measuring device cancels a command pulse from the magnetic tape. In this way the train of pulses from measuring device is locked to the command pulse train to an accuracy of one pulse. Actually an overall accuracy of 0.0002 inch is claimed for the equipment.

The E.M.I. system for continuous position control (see Fig. 5) is somewhat simpler and does not include the intermediate stage of passing the numerical information through a computer. The sets of co-ordinates define marker points at regular intervals of $\frac{1}{8}$ inch round the contour to be cut, and these measurements are punched into a paper tape (in code form) which is used to control the machine tool directly. When the tape is "read" the co-ordinates of a few successive marker points are held in a temporary storage system, and since the tape movement

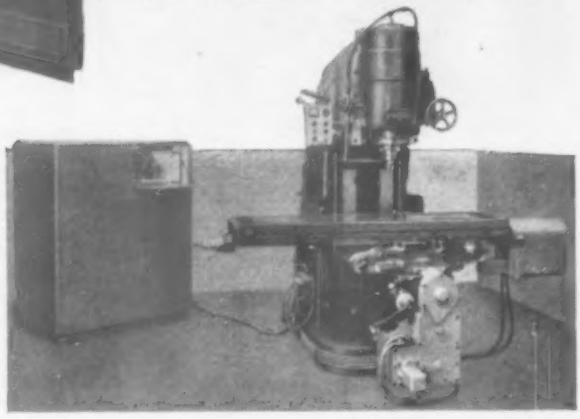


Fig. 5. E.M.I. control equipment used in conjunction with a Cincinatti milling machine. A built-in analogue computer performs the interpolation between the input marker points.

is controlled by the cutting speed of the machine tool the information held always refers to points on either side of the cutting point. The dimensions from the store are then applied to a simple analogue circuit which derives interpolation points lying on a smooth parabolic curve between the marker points. The complete information—marker and interpolation points—is then used to control the servo-mechanisms (using displacement-measuring devices) which position the slides of the work-table.

In this system the accuracy of the information from the control equipment is better than 0.001 inch. At the exhibition the equipment was shown controlling milling machines on the stands of Cincinatti Milling Machines and H. W. Kearns and Company, but because the displacement-measuring devices here were operating from the lead-screws and not directly from the slides of the work-tables the overall accuracy of positioning was probably somewhat worse than this 0.001 inch.

The general impression gained from the exhibition was that although electronically controlled machine tools have aroused a great deal of interest by their novelty, they are not taking on like wildfire and creating a revolution in the industry. There are several possible reasons for this—the limited application of such equipments, their present high cost, practical problems still to be overcome, prejudice against electronics and innate conservatism. In these conditions one must expect the initial progress to be rather slow.

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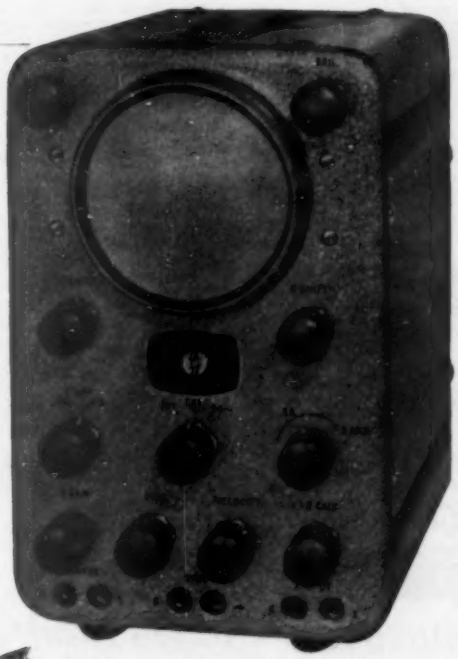

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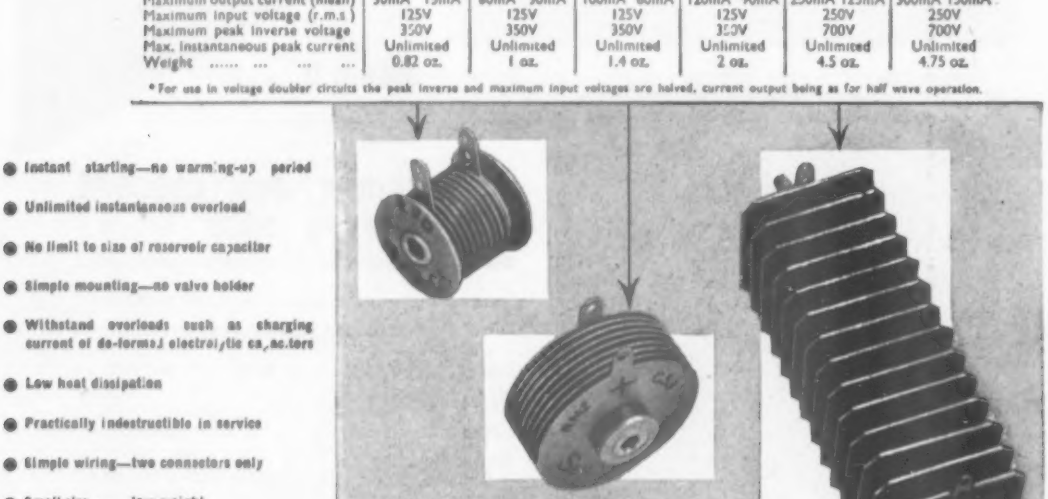

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More Effective Speech

Peak Clipping to Increase Average Modulation

By O. J. RUSSELL, B.Sc., A.Inst.P.

THE "communication effectiveness" of speech transmitters is often enhanced by some form of clipping or limiting device. This is frequently employed in amateur transmitting stations and military communication systems; even in broadcasting stations limiters are used not only to prevent overmodulation on peaks, but also to boost the "commercial" speech level in sponsored broadcasts. As the transatlantic idiom has it, the "talk power" of propaganda stations is also boosted by clipping techniques in order to override jamming.

There is also the possibility of improving intelligibility by modifying frequency response and one often comes across references to "cutting the lows" and "boosting the highs" and to "concentrating on the intelligence-carrying portions of the speech spectrum." Examination of these ideas is clearly necessary. Thus *a priori*, the customary attenuation of frequencies below some 250 c/s would seem to serve no useful purpose if the amplitude of speech components were uniformly distributed over the frequency spectrum. Moreover, telephone systems approximating to a response sharply peaked at 1 kc/s have been used without any complaints of lack of intelligibility. A system peaked at 1 kc/s would clearly tend to overmodulate at the most favoured frequencies in the 1-kc/s region, while the rest of the speech frequency band would not reach overmodulation amplitudes. Hence it would seem that a level speech response curve is required to ensure that the modulation capability of a speech transmitter is not unduly degraded by some frequencies being preferentially boosted in amplitude. However, in a typical male voice the amplitude of the lower bass frequencies is much higher than the middle and upper register components. In fact the energy content of male voices sharply increases towards the low-frequency end of the audio spectrum. By attenuating the lower register below some 250 c/s these high-amplitude components can be reduced, and the intelligence-carrying middle and upper register frequencies may then be raised in amplitude to the maximum modulation capability of the transmitter.

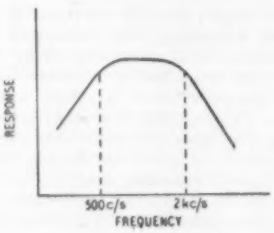


Fig. 1. Typical response curve for speech communication purposes.

That this process of bass attenuation may give useful gain is shown by the fact that some 60 per cent of the energy content of male speech waveforms lies below 500 c/s. Speech in which frequencies below 500 c/s have been removed, still has an articulation index of 95 per cent.[1] As the articulation index is determined on the basis of recognition of "nonsense syllables", and even high-quality systems are rated at an articulation index of 98 per cent, the figure of 95 per cent represents a well-nigh perfect communication system—particularly as plain speech, in contrast to arbitrary "nonsense syllables", has a high degree of redundancy.

The preferential boosting of the middle and upper register is useful, as the general speech level may be lifted once the high-amplitude bass frequencies are attenuated, thus giving an effective gain over a "wide range" speech system. Moreover, in practical communication systems operating under "competitive" conditions, as in amateur and military communications, the frequencies above some 4 kc/s may be omitted. The higher speech frequencies contribute little to intelligibility, and, with sharp tuning of receivers to minimize interference under "competitive" conditions, are in any case removed. Furthermore, an unduly extended upper register may cause severe sideband interference to adjacent communication channels.

The use of a limited speech frequency response (Fig. 1) does not imply that unnatural speech results. The ordinary domestic receiver removes frequencies above 4 kc/s most effectively. Moreover, due to re-synthesis of the missing bass frequencies in the ear from their harmonic components, the speech does not sound "thin" and the characteristic timbre and "personality" of a voice is remarkably well preserved.

Peak/R.M.S. Ratio

Speech clipping introduces further problems. Observation of voice oscillograms shows that sharp spiky peaks extend to an amplitude well above the general level. In fact the ratio of peak amplitudes to r.m.s. amplitudes may be between three and four for speech waveforms as contrasted to the $\sqrt{2}$ ratio for sinusoids. Clearly if the peaks can be clipped and removed without destroying intelligibility, the mean level of the speech waveforms could be increased some three or four times without overmodulation occurring, as compared with the level permissible with the peaks present.

The above reasoning suggests that an effective increase of "talk power" equivalent by some 10 dB could be achieved by incorporating a peak clipper

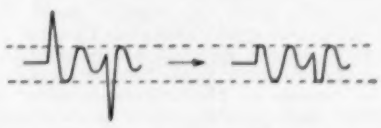


Fig. 2. Sharp peaks in speech waveforms may be clipped without serious effect on intelligibility.

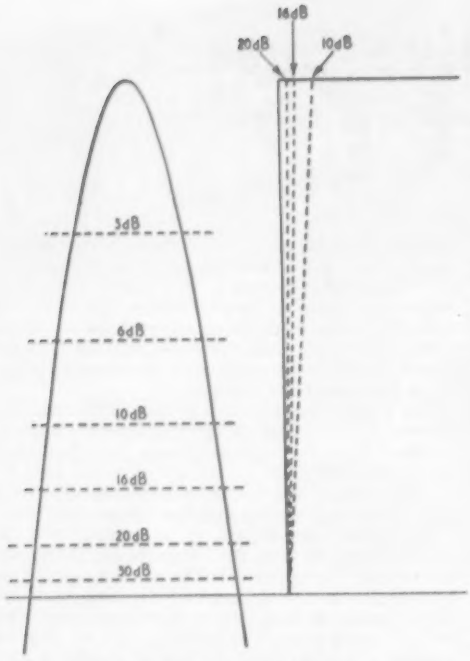


Fig. 3. Showing that as the degree of clipping is increased, a sine wave approaches a square waveform.

in an exisisting modulator. However, it is generally found that some degree of peak clipping takes place in the speech amplifier or modulator stage of an amateur transmitter. When an oscilloscope check reveals that no overmodulation occurs, reports are commonly given of apparent undermodulation. In fact the "full" modulation often heard as clean speech without noticeable "splatter" generally represents almost continuous overmodulation on speech peaks. Due to the sharp nature of the speech waveform spikes, however, the percentage of time during which overmodulation is occuring is small. Really gross overmodulation or speech amplifier nonlinearities are necessary to produce obvious overmodulation on casual listening tests.

Clipper action is idealized in Fig. 2, which shows how peaks may be clipped in speech waveforms without affecting the signal quality noticeably. Speech clippers of the peak limiting type are commonly employed in broadcasting to prevent sudden orchestral transients from overloading the system, as well as to boost the "talk power" of the commercial announcements. Speech waveforms are often asymmetric,[2] with peaks of one polarity higher than the other. Thus it is possible to arrange the speech waveform polarity so that the highest peaks produce positive modulation levels exceeding the 100 per cent mark, while the negative peaks do not extend to the zero level. This gives a limited degree of enhanced speech levels in communications systems. It is uneconomic as the "oversize" modulator must be capable of handling the extreme peaks which may correspond to positive modulation levels of 200 per cent to 300 per cent.

Peak limiting within the speech amplifier is better, as the modulator and transmitter modulation capability need only conform to the usual requirements. However, clipping may be pushed much further than the removal of sharp peaks. It is possible to clip the main speech waveforms. Speech waveforms may be clipped so savagely as to reduce the signal to a series of "on and off" rectangular impulses . . . a sort of "super-morse". In fact speech waveforms may be applied to a trigger circuit to convert them into a series of rectangular pulses. Despite this, intelligible speech can be reconstituted from systems operating on an "infinite clipping" basis.[3] The only factor conveying intelligence in such systems being the crossover points where the polarity of the rectangular pulses change polarity. Practically "infinite" clipping is obtained when the ratio of peak waveform amplitude to clipping level exceeds some 30 to 40 dB. A sine wave clipped to this degree is virtually a square wave, as Fig. 3 indicates. Moreover with a high degree of clipping the speech level is highly compressed, so that the modulation level is virtually independent of the loudness of the speaker's voice, which can change by some 20 dB without the output level changing noticeably. This has the disadvantage that background and room noises are greatly accentuated. A background whisper may for example produce the same output as a speaker close to the microphone.

High clipping levels imply the introduction of a high level of harmonic distortion. It also entails a high level of intermodulation products. Fig. 4 illustrates the intermodulation effect for a weak h.f. speech frequency in the presence of a strong low-frequency component. There are two approaches to the problem of dealing with the distortion products. The usual method is to follow the clipper stage by a low-pass filter attenuating sharply above some 3 kc/s. This prevents harmonics generated in the clipping process from reaching the modulator, so

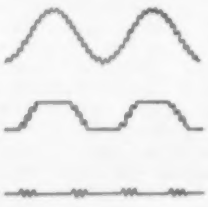


Fig. 4. (a) Small-amplitude h.f. component superimposed on a low-frequency component, (b) after clipping and (c) residual h.f. component.

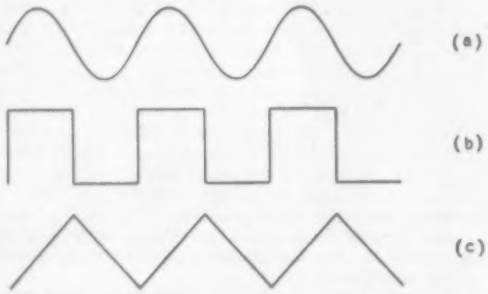
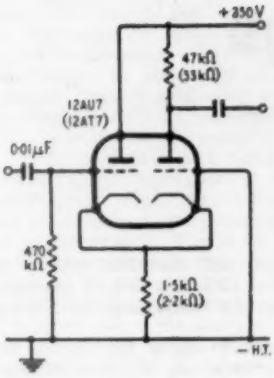
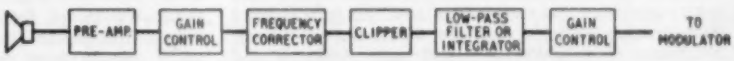


Fig. 5. The sine wave (a) assumes an approximately square shape after amplification and clipping (b), and is restored to a semblance of a sine wave (approx. 12 per cent harmonic distortion) by integration (c).



Left:—Fig. 6. Cathode-coupled clipping stage. The values in brackets should be used with a 12AT7 valve.

Below:—Fig. 7. Schematic diagram of typical clipping circuit sequence.



that the sideband spread is not broadened by "hash" and "splatter". The use of a low-pass filter does not affect distortion products within the 3-kc/s pass band, although perfectly intelligible speech may be radiated with such a filter.

Another approach favoured in some quarters, does reduce distortion products within the pass band. This technique precedes the clipper stage by a differentiating circuit, so there is effectively a top boost of 6 dB per octave. The clipping stage is followed by an integrator stage, which may be regarded as restoring the original frequency balance. Harmonic distortion products are attenuated. This is illustrated (Fig. 5) for a sine wave input. The square wave resulting from the clipper is integrated to a triangular wave. As far as the final result is concerned there is remarkably little difference between a sine wave and a triangular wave, as can be observed when a sine wave of increasing amplitude is fed into such a clipper integrator system. In terms of harmonic distortion, the square wave represents some 50% harmonic distortion, while a triangular wave corresponds to some 12% distortion. Intermodulation products will also be reduced in some cases by the integrator.

The clipping stage may employ many types of circuit such as the classical biased diodes, valves with low anode voltages to limit simultaneously at grid and anode, and so on. One convenient circuit is the so-called "transient-less" clipper shown in Fig. 6. The values shown gave good symmetrical clipping action with 12AU7 and 12AT7 valves. The shorter grid base of the 12AT7 results in the limiting action starting at lower signal inputs than a 12AU7. The simplicity of this circuit, and the symmetry of clipping without critical circuit values are features of some interest.

Circuits of clipping systems are best adjusted with the aid of an oscilloscope. The overall schematic of a clipper system is shown in Fig. 7. The gain control following the clipper stage enables the audio output to be set at a level which does not overmodulate the transmitter. The gain control preceding the clipper stage enables the input to the clipper to be varied from slight clipping action up to the limit set by pre-amplifier gain. In practice it is doubtful whether an apparent effect of more than 10 dB of gain is achieved. Moreover, under conditions of selective fading a heavily clipped system is liable to severe sideband distortion effects unless exalted-carrier receiving techniques are used. This follows because the transmitter operates virtually all the time at the 100% modulation level. When the carrier fades below the sidebands the effect is one of gross overmodulation. Thus a clean speech signal may change to a severely distorted one with a slight change in propagation conditions. The use of exalted-carrier reception methods is clearly the first step that leads logically to the use of single-sideband, suppressed-carrier techniques at the transmitting end. The combination of single-sideband operation together with speech clipping and limiting should provide about the most effective communication system possible for present-day amateur use.

However, while "clipped" speech methods may be used to convert speech into a still intelligible succession of "on-off" pulses, it is necessary to remember that "Vocoder" techniques[4] have shown that speech may be compressed into a few cycles per second of bandwidth by coding speech waveforms into the keying impulses for a small number of waveform generators. The ultimate adoption of such techniques by amateurs may well end the traditional rivalry between telephony and c.w. operators, as speech will then occupy about the same bandwidth as c.w.

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Economy in Receiver Design

Simple Superhet with an Unconventional Smoothing Circuit

By S. W. AMOS, B.Sc.(Hons.), A.M.I.E.E.*

THIS article describes a small medium-wave receiver for a.c. mains operation suitable for use as a second receiver, e.g. in a dining room or a bedroom. It does not require an external aerial but is nevertheless capable of receiving Hilversum, Brussels and a number of provincial Home Services when used in the London area. The receiver is economical of components but it has a.g.c. operating on two valves and the gain control incorporates variable negative feedback. A 5-inch diameter loudspeaker is used and although the upper frequency response is limited by the selectivity of the i.f. transformers, the quality is smooth and pleasant due to reduction of harmonic distortion in the a.f. amplifier by the feedback.

The circuit described here uses international octal valves namely 6K8 (frequency changer), 6K7 (i.f. amplifier), 6Q7 (detector and 1st a.f. amplifier), 6V6 (output valve) and 6X5 (rectifier). The circuit is, however, not at all critical of the valves used and the only component value likely to require adjustment if other types of valve are used is the bias resistor of the output valve. The author has made a receiver of this type using modern B7G and B9A valves namely 12AH7 (frequency changer), 9D6 (i.f. amplifier), EABC80 (detector and 1st a.f. amplifier) and N78 (output); no changes in component values were required other than that mentioned.

Economical Smoothing

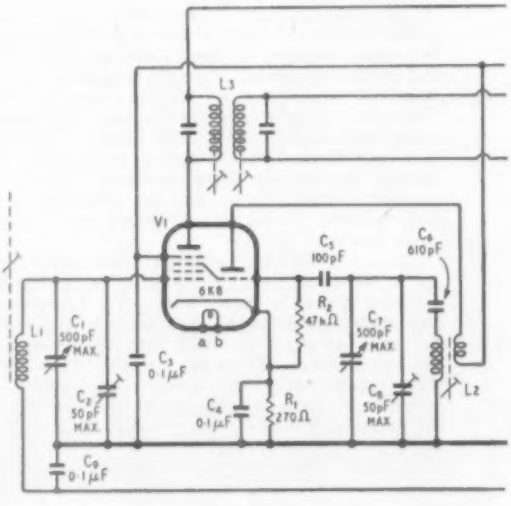
The circuit diagram of the receiver is given in Fig. 1 and the first feature of interest is the smoothing circuit and the method of supplying h.t. to the valve electrodes. The full-wave rectifier circuit is conventional but the anodes of the output stage, i.f. amplifier and frequency changer are all fed directly from the rectifier cathode. At this point the h.t. supply is 260 volts from a mains transformer secondary winding supply 250-0-250 volts. By adopting this technique the current in the smoothing resistor R_9 is reduced to a small value which comprises the screen-grid currents of the output valve, i.f. amplifier and frequency changer together with the anode currents of the oscillator triode and the 1st a.f. amplifier triode. This current amounts to approximately 12 mA, approximately 1/5th the total h.t. current of the receiver. With such a small current the smoothing resistor can have a value as high as 5 kΩ yet still giving a smoothed supply of 200 volts for the screen grid of the output stage and the anode of the 1st a.f. amplifier.

A supply of approximately 100 volts is required for the screen grids of the i.f. amplifier and frequency changer and the oscillator anode; this is obtained from the 200-volt smoothed supply via a series resistor R_{12} of 10 kΩ; a 0.1-μF capacitor C_9 has proved adequate for decoupling the 100 volt supply so obtained.

This simple h.t. supply circuit has proved entirely successful and gives a very low level of hum. This is to some extent due to the use of a pentode as output valve and a triode as 1st a.f. amplifier as illustrated in the following calculations. A 100-c/s ripple voltage can occur at the anode of the output valve (giving hum in the loudspeaker) from three mains sources:

(1) By direct modulation of the anode current of the output stage by ripple on the h.t. supply. If the output valve is a triode this voltage is 2/3rds that at the rectifier cathode because the optimum load of a triode is twice the anode a.c. resistance. Hum due to this cause is reduced by using a pentode because the anode a.c. resistance of this type of valve is of the order of 50 kΩ, 10 times the optimum load (assumed 5 kΩ). Thus the ripple voltage at the anode of a pentode is only 1/11th that at the rectifier cathode. The ripple voltage at the rectifier cathode can be simply calculated as shown in the Appendix: for this particular circuit the voltage is 20 volts peak-to-peak. Thus a triode output stage will give 16.7 volts ripple at the anode and a pentode less than 2 volts.

If a feedback voltage is taken from the anode of the output valve the effective reduction in anode a.c. resistance of the pentode increases the ripple. This can be avoided by taking the feedback voltage from the secondary winding of the output trans-



* B.C.C. Engineering Training Department.

former, when the feedback is effective in reducing hum. This has the additional advantage of reducing any harmonic or attenuation distortion occurring in the transformer. The inclusion of the output transformer in the feedback loop increases the tendency towards oscillation at a frequency outside the passband. The measures adopted to prevent this possibility are discussed later.

(2) By modulation of the anode current of the output pentode by ripple on the h.t. supply to the screen grid. This effect can produce serious hum and smoothing of the screen-grid supply is essential to minimize it. The smoothing circuit employed is, in fact, more than sufficient to reduce hum from this souce to negligible proportions. The smoothing resistor is 5 kΩ and the smoothing capacitor 32 μF. The latter has a reactance of 50 ohms at 100 c/s and the 100 c/s ripple on the 220-volt supply has therefore 1/100th the amplitude at the rectifier cathode, and is only 20/100 = 0.2 volt peak-to-peak value. The voltage gain of an output pentode from screen grid to anode is less than 5 under normal conditions and the ripple is thus unlikely to generate more than 1-volt at 100 c/s at the anode. The smoothing was introduced primarily to reduce the hum described under (3) below and also to minimize the possibility of impressing 100 c/s on the r.f. signals in the frequency changer and i.f. amplifier valves. The 100 c/s ripple on the 200-volt supply is applied at nearly full amplitude to the screen grids of these valves and modulation hum from this cause is a possibility unless the ripple is kept to a small amplitude.

(3) By modulation of the anode current of the output stage by ripple applied to the control grid. This ripple is applied via the anode load resistor R_7 (220 kΩ) and the anode a.c. resistance (say 80 kΩ) of the triode a.f. amplifier which together form a fixed potential divider across the 200-volt supply. The step down ratio is 4 : 1 and the ripple at the control grid is thus 0.2/4=0.05 volt. If

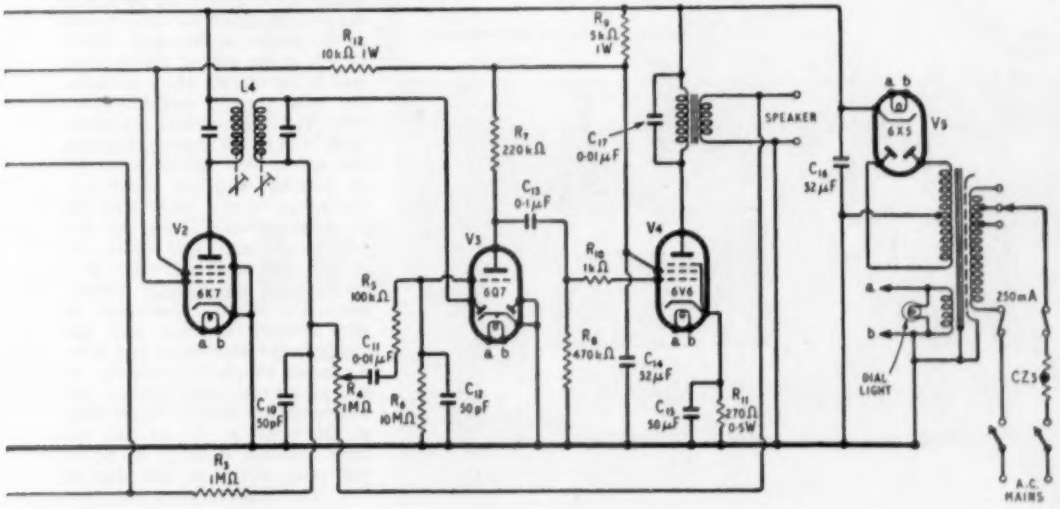
Front view of the receiver.

the gain of the pentode is 30, the ripple at the anode from this source has an amplitude of 0.05 × 30 = 1.5 volt peak-to-peak, less than that due to direct modulation of the anode current by the ripple at the rectifier cathode. If the 1st a.f. amplifier had been a voltage-amplifying pentode with an anode a.c. resistance of 1 MΩ, the ripple at the pentode anode would have been 5 times greater, i.e., 7 volts, possibly sufficient to produce audible hum.

These calculations show that by using the types of valve specified the hum can be kept to negligible proportions in spite of resistance smoothing and without the need for an additional smoothing section for the h.t. supply to the triode anode. The calculated ripple voltages at the pentode anode apply when the gain control is set at maximum, for there is then no negative feedback. When the gain control is turned down for reception of a strong signal, negative feedback is automatically applied and the ripple voltage is less than calculated above. In practice the hum level is negligible at all settings of the gain control.

We shall now consider the design of the valve circuits in detail, beginning with the mains equip-

Fig. 1. Complete circuit diagram of receiver. All resistors are rated at ½ watt unless otherwise specified. L_1, 40 turns 9/45 Litz wound to occupy 1¼ in length on paper sleeve on Mullard "Ferroxcube" rod, type FX 1247; L_2, Osmor type QO8; L_3, L_4, Eddystone type 851 or Wearite type M800.



ment which is conventional, except for the provision of the Brimistor CZ3 in the primary circuit of the mains transformer. This is included to reduce the magnitude of the surge current immediately after switching on, so prolonging the life of the valves and the dial light. It also permits the use of 250 mA mains fuses; without the CZ3 the fuse rating would need to be raised to at least 1 amp to stand the surge current.

Grid-current Bias

The a.f. amplifier consists of the triode voltage amplifier V3 and the pentode output stage V4. The two valves are RC-coupled and V4 has a bias resistor R_{11} and decoupling capacitor C_{12}. V3 is biased by grid-current flow in R_8 which has the high value of 10 MΩ. This saves the cost and bulk of a cathode decoupling capacitor. If a triode valve of a type different from that specified is to be used, it is necessary to check that it is suitable for biasing in this manner. The diode load resistor R_4 functions as gain control and the components R_5 and C_{13} are an i.f. filter. These components are placed subsequent to the gain control deliberately. If placed between the diode output and the gain control, it would not be possible to remove the feedback completely at the maximum setting of the gain control.

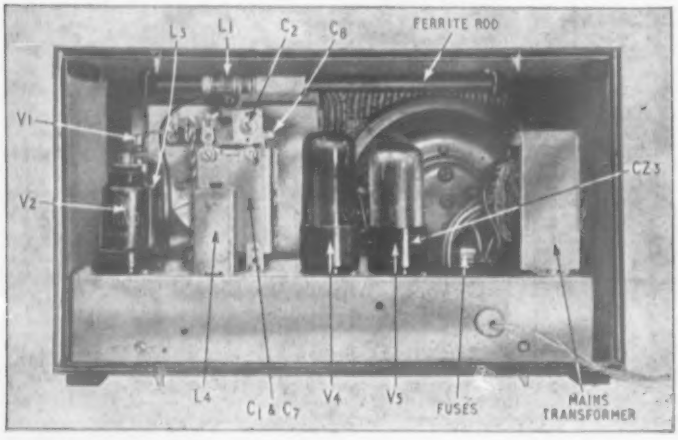
To receive weak signals the full gain of the receiver may be necessary, but for local-station reception, where the full gain is not required, it is possible to employ negative feedback to improve quality by reducing harmonic distortion. In the feedback circuit used by J. L. Osbourne[1] the gain control is used simultaneously to control the magnitude of the signal applied to the a.f. amplifier, and also the feedback factor. He achieved this by returning the gain potentiometer to the junction of two resistors connected in series across the secondary winding of the output transformer, the resistance values being chosen to avoid any possibility of oscillation at a very high or very low frequency. However, it was found possible to avoid instability by suitable design of the a.f. amplifier and the two resistors are unnecessary. Thus the volume control can be returned to one end of the secondary winding and, at zero setting of the volume control, the whole of the secondary voltage is used for feedback. The use of the volume control for two purposes alters its effective law and a linear control gives smoothest control of volume; a logarithmic control tends to be fierce near its maximum setting.

Instability tends to occur in a feedback amplifier at frequencies outside the passband, in an a.f. amplifier at very low frequencies such as 1 or 2 c/s (an effect known as motor-boating) or at a high frequency such at 50 kc/s. Oscillation at such high frequencies is, of course, inaudible but can nevertheless ruin the performance of the amplifier by causing excessive noise or low power output. This oscillation is perhaps best detected by an a.c. meter connected across the output; a steady reading is obtained even with no input to the amplifier. Instability is caused by phase shifts in the amplifier and can be avoided by correct choice of the time constants controlling the phase shift. At very low frequencies the significant time constants are R_9C_{11}, R_8C_{13} and the anode circuit of the output valve. The latter time constant is given by the quotient of the primary inductance of the output transformer (say 8 henrys) and the load resistance (say 5 kΩ) and is equal to $L/R = 8/(5 \times 10^3)$ second = 1.5 milliseconds. As shown by Brockelsby[2] the instability can be avoided by making the other two time constants large compared with this; in this way two of the phase-shift circuits are made wide-band and the third is narrow-band. The values chosen are $R_9 = 470$ KΩ, $C_{13} = 0.1$ μF giving a time constant of 50 milliseconds and R = 10 MΩ C = 0.01μF giving a value of 100 milliseconds and have proved effective in avoiding instability in three receivers all using different makes of output transformer. The intervalve time constants are much larger than is necessary purely from considerations of frequency response. If feedback were not used it would be quite satisfactory to have time constants as small as 0.006 second (e.g., 680 kΩ and 0.01 μF), for this corresponds to 1 dB loss at 50 c/s.

The phase shift in the a.f. amplifier at frequencies immediately above the passband occurs principally at three points in the circuit; in the anode circuit of V3, in the output transformer and in the circuit which includes the gain control and i.f. filter. The circuit controlling the phase shift at the first point comprises the anode load resistance of V3 in parallel with the anode a.c. resistance of the valve and the stray capacitance shunting the two resistances. The phase shift in the output transformer is a function of the leakage inductance, the shunt capacitance in the primary winding and the loudspeaker impedance and is by no means simple to calculate. If no additional components are introduced to control phase shift at this point in the circuit, the time constant is likely to be of the same order as that due to

(*Continued on page 391*)

Rear view of receiver with back removed showing the ferrite rod and method of mounting.



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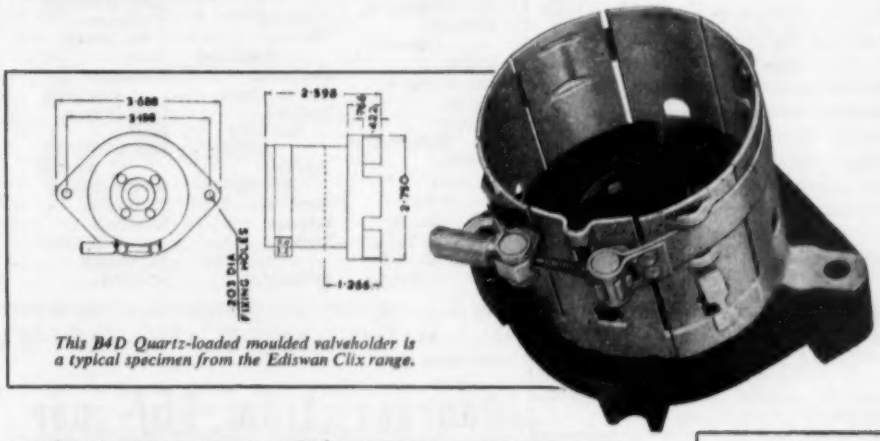

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V3 anode circuit. The phase shift introduced by the gain control and i.f. filter is also of the same order as the two previous circuits and, when conventional component values are used, the overall phase shift generally gives continuous oscillation around 50 kc/s when the gain control is near zero setting. To obtain stability it is necessary to give one of these three phase-shift circuits a larger time constant. We have then satisfied the criterion of Brockelsby that two of the phase-shift circuits give wide-band responses and the third is narrow-band. One way of achieving this is to connect a capacitor in parallel with the primary winding of the output transformer. A value of 0.01 μF has proved suitable.

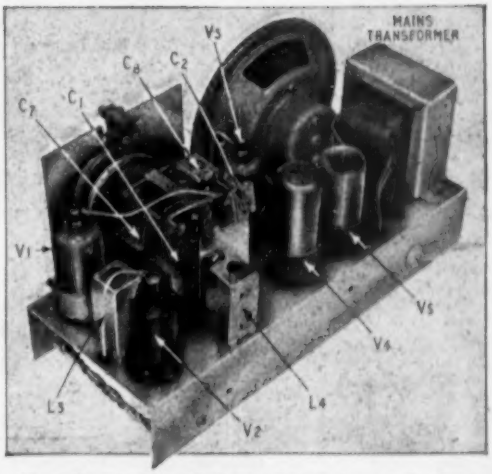
At the frequencies at which instability is likely to occur the components effectively controlling the phase shift are the anode a.c. resistance of the output valve (say 50 kΩ) and the capacitor C_{17}, giving a time constant of $0.01 \times 10^{-6} \times 5 \times 10^{4}$ second = 500 microseconds, very large compared with that of the other two phase shift circuits. This value of capacitance does not cause any perceptible loss of "top" when the gain control is advanced to maximum setting where there is no feedback. This value of C_{17} has given unconditional stability in a number of receivers employing this circuit and constructed with different types of output transformer.

I.F. Stages

The gain and selectivity of a superhet receiver are determined almost entirely by the properties of the i.f. transformers and these must therefore be well designed. The space available for these components is limited and miniature types 13/16-inch square were used. The types listed under Fig. 1 must be used if the performance of the original receiver is to be duplicated. An interesting feature of some of these transformers is that the coupling between the windings is both inductive and capacitive. These two forms of coupling can aid or oppose and thus there may be a significant change of gain on reversing the connections to one winding. In particular it was found that higher gain can be obtained from Eddystone transformers in this particular receiver if the connections to one winding are reversed relative to those indicated on the can.

The cathode of the i.f. amplifier is directly earthed no automatic bias components being included. This economy is justified because there is a standing bias of -1 V on the a.g.c. line from the signal diode and this provides grid bias in the absence of a signal.

The frequency changer circuit is conventional and here it was found that automatic bias is essential because the 6K8 gives maximum conversion conductance with approximately -3.0 volts on the control grid. The oscillator circuit is a tuned-grid type, C_8 and C_9 being trimming and padding capacitors respectively. The value of the padding capacitor proved to be unexpectedly critical and it is recommended that this component should have a tolerance of no more than $\pm 2\%$. This is partly due to the use of a ferrite-rod aerial in the signal-frequency circuit. The Q value of this circuit is very high—about 300—and even a small tracking error results in a significant loss. The tuning of a superhet receiver is, of course, fixed by the i.f. and oscillator circuits and tracking errors result in a loss due to mistuning of the signal-frequency circuit. At



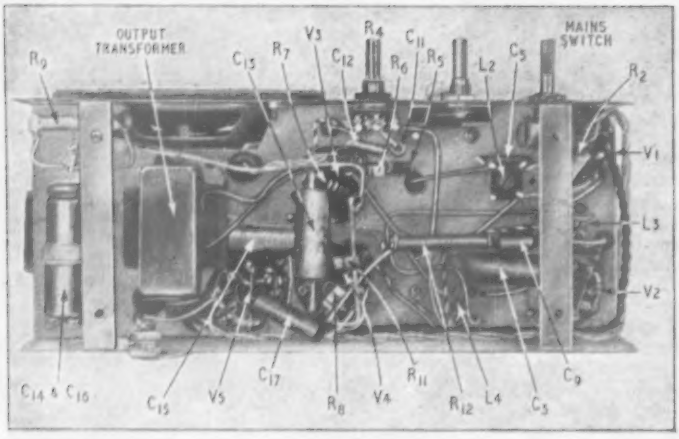
View of upper side of chassis showing layout of valves, mains transformer, tuning capacitor and i.f. transformers.

1 Mc/s a tracking error of as little as 5 kc/s results in a loss of 10 dB if the Q value is 300. Tracking error must thus be minimized and the authors carried out a series of experiments, using different values of padding capacitance, to determine the capacitance for least loss averaged over the medium waveband. The reduction of these losses to a minimum requires correct choice of alignment frequencies as well as correct padding capacitance and it was found that best results were obtained by aligning at 1530 kc/s and 620 kc/s and by using a padding capacitance of 610 pF. This gave zero loss at 1050 kc/s and at the alignment frequencies with maximum losses of 6 dB at 550 kc/s, 850 kc/s, 1300 kc/s and 1600 kc/s.

The signal-frequency circuit consists simply of a Litz winding on a ferrite rod 8 inches long and $\frac{3}{4}$ inch diameter (Mullard type FX 1247). The coil consists of 40 turns of 9/45 Litz wound to occupy a winding length of $1\frac{1}{4}$ inches on a paper sleeve which is free to slide along the rod. With this number of turns the normal position of the sleeve is approximately 2 inches from one end of the rod and a slight movement of the coil produces a comparatively large change of inductance. This movement is used in aligning the receiver at the low-frequency end of the band. Alignment at the high-frequency end is achieved by variation of the trimmer C_2 which is mounted in a vertical position on the rear section of the two-gang tuning capacitor so that it can be adjusted when the receiver is in the cabinet.

Alignment

Adjustment of the i.f. and oscillator sections of the receiver can be carried out with the receiver on the bench but in the models constructed by the author the ferrite rod is mounted in the cabinet and the receiver must be in the cabinet for adjustment of the signal-frequency circuits. With the receiver on the bench adjust a signal generator to give a modulated output at 465 kc/s and apply the output to the receiver; the output may be connected directly across L_1. With the receiver gain at maximum adjust the level of the signal-generator



Under-chassis view identifying the principal components.

output until the modulation is barely audible. Adjust the two dust-iron cores of both i.f. transformers to give maximum output from the receiver. As the receiver output increases, decrease the output of the generator to keep the receiver output barely audible.

To align the signal-frequency circuits, a different form of coupling is required between generator and receiver. A method which has proved successful is to connect the generator output to the ends of a small coil, which need consist only of a few turns, looped over the ferrite rod at the end remote from the winding L_1. Set the generator to give a modulated output at 1600 kc/s, the receiver tuning to 187 metres and tune the signal in by adjustment of C_8. Now set the generator to 545 kc/s, the receiver tuning to 550 metres and tune the signal in by adjustment of the dust-iron core of L_2. Retune the generator to 1600 kc/s, the receiver to 187 metres and repeat the adjustment of C_8. Now return to the low-frequency end of the band and repeat the adjustment of L_2. Continue these adjustments until no further change in setting of C_8 or L_2 is required. The frequency range of the receiver is now correct and the indications of the tuning scale should be accurate. At this stage it is a good plan to check the accuracy of scale readings at a few points in the band, e.g., 750 kc/s (400 metres), 1000 kc/s (300 metres), 1200 kc/s (250 metres) and 1500 kc/s (200 metres). Any slight errors can sometimes be minimized by re-setting the pointer with respect to the tuning capacitor and re-aligning.

Aerial Adjustment

The receiver must now be mounted in the cabinet in order to align the aerial input circuit. Set the signal generator to 1530 kc/s and tune in the signal by rotating the tuning control to approximately 196 metres. Adjust C_9 to give maximum output from the receiver. Set the signal generator to 620 kc/s and tune in the signal by rotating the receiver tuning capacitor to approximately 484 metres. Slide L_1 along the ferrite rod to the position which gives maximum receiver output. Retune the generator and receiver to 1530 kc/s and repeat the adjustment of C_9. Repeat the adjustment of L_1 at the low-frequency end of the band and continue these two adjustments until no further re-setting of C_9 or L_1 is required. The alignment is now completed and the paper sleeve carrying L_1 should be secured to the ferrite rod.

The receiver is housed in a wooden cabinet measuring 11½ inches by 7 inches by 5 inches and the steel chassis supplied with the cabinet measures 10½ inches by 4 inches by 1¾ inches. The chassis was intended for a 3-valve t.r.f. receiver using a metal rectifier and was modified for the superhet by punching two large holes for the additional two valves and a number of smaller holes for the two i.f. transformers. The layout of the receiver is evident from the photographs and except for the provision of a small screen and the method of supporting the ferrite rod does not require detailed description. The screen is necessary to prevent slight instability and shields the grid lead of the first i.f. transformer from the anode pin of the i.f. amplifier. The ferrite rod could be supported by brackets mounted on the chassis, permitting the receiver to be completely aligned on the bench but in the model illustrated the rod is supported by two rubber grommets held in position by short lengths of wire which fit into the grooves and are secured by short wood screws to the underside of the top of the cabinet. The wire loops must not form closed loops around the rod for these, if closely coupled to the tuned winding, may reduce the effective Q-value. The ferrite rod should be handled with great care because it is extremely brittle and will almost certainly break if allowed to fall more than a few inches on to a hard surface. The ferrite rod is directional, giving maximum signals when broadside on to the direction of the transmitter. It may happen if the rod is mounted parallel to the long dimension of the chassis as shown in the photographs that the signals from the local station are at a minimum with the receiver placed in the desired position. This difficulty can be avoided by arranging for the ferrite rod to be at an angle to the long dimension of the chassis. The angle cannot exceed approximately 30 degrees but this may be sufficient to avoid the difficulty. The choice of position for the ferrite rod is further complicated by a hum which becomes apparent on strong signals when the rod is situated near the mains transformer. This effect may be confused with modulation hum but appears to be due to the properties (possibly non-linearity) of the ferrite rod and can be minimized by suitable choice of position.

References

[1] J. L. Osbourne. "Midget Sensitive T.R.F. Receiver." *Wireless World*, April, 1954.

[2] C. F. Brocklesby. "Negative Feedback Amplifiers." *Wireless Engineer*, February, 1949.

APPENDIX

THE voltage across the reservoir capacitor connected across the output of a rectifier consists of a series of

exponential rises, coinciding in time with the periods of conduction of the rectifier, alternating with exponential falls due to discharge of the capacitor by the current taken by the load. To simplify calculation of the amplitude of this ripple, we can assume that the voltage has a sawtooth form, rising instantaneously to the maximum value when the rectifier conducts and falling linearly in the intervening periods. The assumption of a linear fall in voltage is justified if, as is usually true in practice, the fall is a small fraction of the maximum voltage across the capacitor. If the load current is assumed to have a constant value i during discharge periods, the charge q lost by the capacitor in one of those periods is it, t being the duration of the period. This produces a fall in voltage given by q/C, i.e., it/C.

For a full-wave rectifier the discharge period t is half that of the alternating voltage supply and is thus given by $1/2f$.

Substituting for t in the above expression gives the general result—

$$\text{Ripple voltage (peak-to-peak value)} = \frac{i}{2fC}$$

For the receiver described in the article $i = 60$ mA, $f = 50$ c/s and $C = 32\mu$F. Substituting these values in the general expression—

$$\text{Ripple voltage} = \frac{60 \times 10^{-3}}{2 \times 50 \times 32 \times 10^{-6}} \text{ volts}$$

$$= \frac{60 \times 10^{3}}{2 \times 50 \times 32}$$

$$= \frac{60 \times 10^{3}}{64 \times 50}$$

$$= 20 \text{ volts approximately (peak-to-peak)}$$

COMMERCIAL LITERATURE

Standing-Wave Indicator (for waveband centred on 3.2 cm); rotary attenuator, 3.2 cm, using nichrome-coated glass vanes; and monitor diodes for 3.2 cm and 10 cm. Leaflets for their catalogue of microwave instruments from Elliott Brothers (London), Elstree Way, Borehamwood, Herts. Also a price list and a leaflet on power supplies for klystrons.

Silvering Glass and Ceramics to provide a surface for soft-soldering. Two-coat method using silver pastes, described in Electrical Engineering Data Sheet 1300:473 from Johnson, Matthey and Co., 73-83, Hatton Garden, London, E.C.1.

Non-Destructive Testing of engineering materials. Booklet on electronic methods from A. E. Cawkell, 6-8, Victory Arcade, The Broadway, Southall, Middlesex.

Thermistors, as used in receivers for surge suppression, picture-height correction, temperature compensation, etc. Leaflet giving technical data, equivalents, prices and list of receivers in which Mullard Varite types are fitted, available to dealers from Mullard, Century House, Shaftesbury Avenue, London, W.C.2.

Bench-Type R.F. Heater, 750-W, for "pre-heating" plastics powders before they are put in moulds. Will plasticize at rate of up to 8oz per minute. Has air-cooled triode oscillator (35-36 Mc/s) and xenon rectifiers, with process timer and automatic lid opening. Leaflet from Radio Heaters, Eastheath Avenue, Wokingham, Berks.

Instrument A.C.-D.C. Converter, using thermocouple, for precise measurements of a.c. voltages and currents with d.c. potentiometers. Voltage ranges from 7.5 V to 300 V and current ranges from 18 mA to 5 A; accuracy $\pm 0.05\%$ over frequency range of 25 c/s to 10 kc/s. Leaflet from the Croydon Precision Instrument Company, 116, Windmill Road, Croydon, Surrey. Also a leaflet on **Precision Instrument Switches**.

Components and Accessories; the July, 1956, illustrated catalogue from Radiospares, 4-8, Maple Street, London, W.1.

Direct Reading Magnetometer, for measuring fields of transformers, electric motors, focusing electromagnets, etc. Three ranges: 0-5, 0-50 and 0-500 oersteds, using one probe. Short-term accuracy better than $\pm 1\%$. Calibrating solenoid available if required. Leaflet from Newport Instruments (Scientific and Mobile), Newport Pagnell, Bucks.

High Quality S.R. Equipment; amplifiers, pickups, loudspeakers and cabinets, control units, tuners, gramophone motors, tape recorders and other accessories by well-known makers. Also suggestions for equipment combinations, with prices. Illustrated catalogue from the Classic Electrical Company, 352-364, Lower Addiscombe Road, Croydon, Surrey.

Band-III Television Pre-amplifiers, for fringe areas, using earthed-grid low-noise stage followed by neutralized triode stage, giving a gain of 20 dB at full bandwidth. Two aerial inlets, for Band I and Band III, with changeover switch; also a gain control. Leaflet from Spencer West, Quay Works, Great Yarmouth, Norfolk.

Crystal Calibrator for communications receivers. Usable range to 55 Mc/s with check points at every 100 kc/s. Also a Codan squelch unit, a mechanical filter adapter and two loudspeakers. Leaflet on accessories designed specifically for Hammarlund communication receivers, from the Hammarlund Manufacturing Company, 13th East 40th Street, New York 16, N.Y., U.S.A.

Small Direction Finding Aerial (marine) weighing only 17oz, for mounting on hand bearing compass. Can be used with any communications receiver covering beacon signals (290-310 kc/s) and includes a sense finder. Range 50 miles with 20 μV receiver sensitivity. Descriptive leaflet from Brookes and Gatehouse, Shirley Holms, Lymington, Hants.

Waveguide Attenuators, fixed and variable, high-power impedance meters, tees, fixed and sliding terminations and u.h.f. coaxial directional couplers are among the new items in a catalogue of u.h.f. and microwave test equipment from the Narda Corporation, 160, Herricks Road, Mineola, L.I., New York, U.S.A. British representative at 86, Holly Road, Uttoxeter, Staffs.

Resistance Boxes with low, constant switch contact resistance and bifilar windings to reduce inductance. Three or four dials provided, with resistance coil values from 0.1 Ω to 100 kΩ. Accuracy of adjustment 0.1%. Also Wheatstone bridges—precision, portable and self-contained types. Leaflet from the Doran Instrument Company, Stroud, Glos.

Composite Band-I/Band-III Television Aerials with Band-I dipole element "electronically coupled" to Band-III resonator, thereby eliminating coupling bars, so avoiding impedance mismatching, and utilizing Band-I elements on both bands. Leaflet, among others, from Antiference, Bicester Road, Aylesbury, Bucks.

Tape Recorder, two-speed, with 10-inch elliptical loudspeaker in detachable lid. Facility for mixing two inputs, and amplifier which can be used separately for reproduction from tuner units, etc. Leaflet on the Wyndsor Regent from the Magnetic Recording Company, 99, Shacklewell Lane, London, E.8.

Communications Receiver with expanded tuning scale, enabling frequency to be read very accurately, and facility for choosing L/C ratios of tuned circuits for optimum performance. Coverage of amateur bands from 1.8 Mc/s to 30 Mc/s in six ranges. Detailed description of the Eddystone Model "888" from Stratton and Company, Alvechurch Road, Birmingham, 31.

Clip-on Voltmeter-Ammeter, measures current without breaking circuit by means of magnetic induction in current-transformer core. Five current ranges, from 0-10 A to 0-1000 A a.c. and two voltage ranges 0-150 V and 0-600 V a.c. Also a high-frequency model (up to 400 c/s, 2.5 kc/s or 20 kc/s depending on current). Leaflet from Ferranti, Hollinwood, Lancs.

SEMI-CONDUCTORS—2

Another Step on the Way to Transistors

By "CATHODE RAY"

QUITE clearly we will all have to become acquainted with transistors—those who are not already. And one cannot go far without at least some notion of what goes on in the materials of which they are made—semi-conductors. Last month we got the length of seeing why semi-conductors semi-conduct. Unlike metals, which are good conductors of electricity because all their atoms have active or "valency" electrons that are free to drift about as electric currents, semi-conductors' valency electrons are in fixed jobs, linking up with their mates in adjoining atoms to form a regular lattice-like structure that we know as a crystal. Unlike perfect insulators on the other hand, these permanently employed electrons are not altogether immune from being tempted into absenteeism. Typical tempters are heat and light. At ordinary room temperatures an appreciable proportion—getting on for one in a million—of the valency electrons in germanium have shaken loose and are available for electric currents. It is the relative fewness of these absentee electrons that accounts for the "semi." In silicon they are fewer still, unless the temperature is considerably higher.

The atoms from which electrons have gone ("holes") are minus one negative charge. Minus negative is the same thing as plus positive, so electrically these deprived atoms are positive charges. Unlike the freed electrons, they are fixed parts of the crystal structure. But when an electron moves from a complete atom A to a hole B it is just as if the hole moved from B to A. The point of looking at it like this is that a very large number of short electron movements can often more easily be described as perhaps only one long hole "movement." So if, for instance, an electron shook loose in the middle of a crystal of germanium, to the ends of which a battery was connected, the electron would be attracted to the positive terminal, constituting a tiny electric current; at the same time the hole left behind might quickly be filled by an electron from a near-by atom on the negative side; that hole might be filled by one still nearer the negative terminal; and so on, the net result being the same as if the original hole had moved to the negative terminal, constituting another tiny electric current to add to the electronic current. Rather surprisingly, it is found that holes in semi-conductors can move about half as fast as electrons.

That was as far as we got last month, and before going on it would be as well to make quite sure of this hole business, and especially what is meant in transistor literature when it said that holes move. A thing to remember is that only the electrons *really* move; strictly speaking the holes are fixed, but some kinds of electron movement have the same electrical effect as if holes moved, and are more conveniently described and calculated as such. Fig. 1 is a picture of a dozen people forming a queue (a), for whom the management have thoughtfully provided seats. No. 6 is called in first, so he leaves his seat and goes forward (b), thus creating a vacancy or "hole." This vacancy, strictly speaking, is a fixed seat; but if, in the natural desire to get as far forward as possible, No. 7 moves into it, then No. 8 moves into the newly created vacancy, and so on; the final result is as if the influence that induced the forward movement of person No. 6 also had the effect of repelling the "hole" to the rear (c). The total human current is the movement of a man from position 6 to the left hand or positive end, plus all the short movements of Nos. 7 to 12 inclusive; but the latter part can be described much more concisely as the movement of a vacancy from position 6 to the right-hand or negative end, *or* as the movement of a person from 12 to 6.

Holes, then, are imaginary positive charges, about half as mobile as electrons, used for convenience as an alternative way of describing certain real but complicated movements of electrons in the opposite direction.

Intrinsic Conductivity

So far we have an explanation for the small but appreciable conductivity of pure semi-conductors such as silicon and germanium, and also for its fairly steep increase with rise of temperature; because the normal state of these materials is full employment of electrons on fixed sites, they tend to be insulators; but except at very low temperatures this state is upset by a small proportion of electrons being freed by heat energy The actual proportion depends on the temperature (the higher the greater) and on the structure of the atoms (i.e., on the material; the proportion is much greater in germanium than silicon). In a given material at a given temperature it cannot be altered. So it is called the *intrinsic* conductivity* of the material.

That doesn't get us very far towards transistors, or even crystal rectifiers, for intrinsic conductivity is no more than an incidental nuisance. It means that an e.m.f. always causes some current through semi-conductor devices, even when they are supposed to be biased to "cut-off." And the increase with temperature means that germanium devices are more or less out of action at the temperature of boiling water, though silicon can still be used—hence the development effort being put into silicon at the present time.

Light has been mentioned along with heat as a disturbing influence in semi-conductor crystalline structure and, therefore, a causer of conductivity. But it is a simple matter to keep light out where it

* Does anyone wonder what is the difference between conduction and conductivity? It is rather like the difference between production and productivity: a production of 1,000 tons of coal doesn't tell one whether it was obtained efficiently or not; for that one needs to know the productivity, which is the production per man per week or shift. Conductivity is the proper figure for comparing the conductions of different materials, in amps per volt per metre (or centimetre) cube.

isn't wanted (in ordinary transistors) and to let it in where it is—in photo-transistors, which enable a current to be controlled by light. So we are not going to bother about light just now.

Why use materials such as germanium, when they are subject to this intrinsic conductivity nuisance? Well, it happens that atomic structure which is liable to have the odd electron knocked off here and there by heat energy is also the kind that enables rectifiers and transistors to be made. That comes about in a curiously indirect sort of way. The only hint so far lies in a word you probably overlooked—"pure." When the semi-conductors are not pure, the picture becomes much more complicated. And for this purpose the standard of purity is so high that it would make the best "pure water supply" look like a cesspool. The uninitiated might suppose that if there were no more than one impurity atom to every 100,000,000 of germanium the material would reasonably pass as "pure." The chemical analyst would have no doubts about it. Yet this incredibly small impurity is enough to have quite an effect on the conductivity.

Cuckoo in the Nest

As it happens, the main natural impurity in germanium is arsenic, which is No. 33 in the list of elements. Germanium, you remember, was 32, so each of its atoms has 32 electrons, of which (as we saw last month) all but four—the valency electrons—can for our purpose be lumped in with the nucleus to form a body having a net positive charge equal to four electron units. So we simplified the diagram of a normal neutral germanium atom down to Fig. 2(a)—the augmented nucleus with its net charge of +4 surrounded by its four valency electrons each with a −1 charge. These are the electrons that link up with four neighbouring atoms to form the crystal lattice. On the same basis, as we might expect, the diagram of an arsenic atom looks like Fig. 2(b).

Now the interesting thing is that the arsenic atoms present in a piece of germanium find themselves accepted as units in the crystal lattice, just like a young cuckoo in a nestful of sparrows. But, of course, only four of the five electrons can find fixed employment; the odd one has to seek his fortune elsewhere. So in germanium with arsenic impurity there are free electrons, over and above any that are released by heat energy. The conductivity is

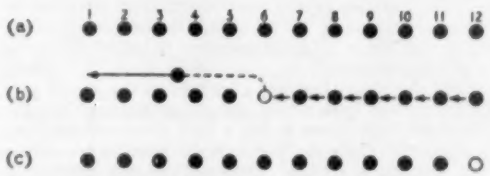


Fig. 1. (a) Queue of people waiting in seats. (b) No. 6 is called forward. (c) Apparent movement of his vacant seat backwards.

Fig. 2. Simplified diagrams of atoms: (a) tetravalent; (b) pentavalent; (c) trivalent.

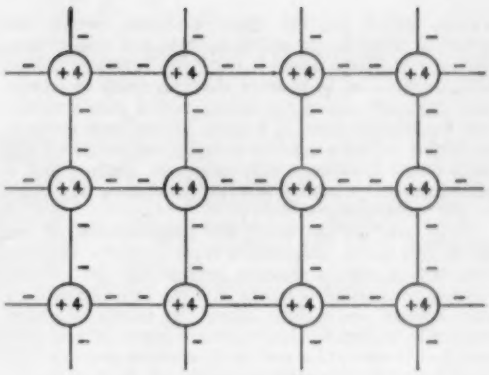


Fig. 3. Diagram of pure crystal lattice built up of Fig. 2(a) atoms.

consequently greater. Even with what would be considered chemically an insignificant amount of impurity the conductivity might be 100 times greater. In silicon, the effect would be even more marked if one could compare it with really pure silicon, which unfortunately is difficult to obtain.

And so another of the peculiarities of semi-conductors—the widely varying conductivities of "chemically pure" samples—has been accounted for. But it still doesn't seem to get us very near transistors.

However, arsenic (or phosphorus, or antimony, whose atoms also can be represented as in Fig. 2(b)) is not the only kind of impurity that can get into the semi-conductor crystal lattice. There is gallium, which, being element No. 31, looks like Fig. 2(c). Others in the same group are aluminium and indium. These come with only three valency electrons per atom, so when they are in the lattice they resemble germanium atoms from which an electron has been shaken out by heat—except that the nucleus has only three units of positive charge instead of four, so the atom as a whole is neutral. But they are, in effect, holes.

Vital Minority

Being familiar with the nomenclature of valves according to the number of their electrodes, we do not have to be Greek scholars to see why the atoms diagrammed in Fig. 2 are referred to as tetravalent, pentavalent and trivalent respectively.

The position, then, is that when either of the tetravalent elements germanium or silicon is contaminated by even minute proportions of a pentavalent element such as arsenic its electrical conductivity is increased well above the intrinsic conductivity of the pure element, because of the presence of one surplus electron per impurity atom. And with trivalent impurity much the same thing happens because of the presence of one hole per impurity atom. In the first case the conduction is by electrons; in the second it is (or, if you are a stickler for accuracy, *appears* to be) by holes.

We are now getting to the heart of the matter. And for quick reference to these two different impurity materials there are some technical terms, which can easily be remembered by noting the occurrence of the letters *n* and *p*. Pentavalent

atoms, which provide spare electrons, which are negative charges, are called donors; and a semi-conductor containing them is *n*-type. Trivalent atoms, which are holes, or positive charges, ready to receive electrons, are called acceptors; and a semi-conductor containing them is *p*-type. Note very particularly that calling a material *n*-type does *not* mean that as a whole it is negatively charged. Both *n* and *p* materials are normally neutral; the letters refer only to the loose charges.

And now we can carry the simplification of our atom and lattice diagrams a stage farther. We saw last month that a perfect germanium (or silicon) crystal consists of a lattice of Fig. 2(a) atoms, each one holding on to four others, as shown diagrammatically in Fig. 3. Each atom is electrically neutral and fixed—except for the small minority disturbed by heat, which we are going to ignore for the time being. So electrically the material hardly exists; Dr. Shockley has in fact drawn an analogy between it and the vacuum in a valve. It merely provides a space for the impurity electrons and holes to play about in. We are going to omit it entirely from our following diagrams in order to concentrate attention on the very small but vital minority of impurity atoms. These of course are scattered at random throughout the crystal, so form no particular pattern. And only the net electrical charge of each unit will be shown. There is first the loose electron, shown as before by a single minus sign. Then there is the hole which, although not truly movable, does (owing to successive transfers of electrons) virtually move nearly as readily as an electron; it is represented by a plus sign. Then a donor atom (Fig. 2(b)) having lost its one unemployed electron is a fixed unit positive charge, represented by a plus sign in a ring; and lastly an acceptor atom (Fig. 2(c)) is a fixed negative charge, represented by a minus sign in a ring. Fig. 4 shows a sample of each.

It would be a good idea at this point if you would make sure that the meaning of *n* and *p* material, and the conventional symbols just explained, have been grasped, by drawing diagrams of samples of these two materials using the symbols. And then checking that they agree with Fig. 5. Remember that these diagrams show *only* the impurities; the millions of times as many germanium and silicon atoms are there but not shown. And whereas the minus signs in Fig. 5(a) represent real electrons floating around, the plus signs in Fig. 5(b) represent only the fact that *p*-type material behaves very much as if there were real positive charges, analogous to electrons, floating around. The real cause of this—and I am sorry if my insistence on this point is becoming a bore—is the movements of electrons from one acceptor to another.

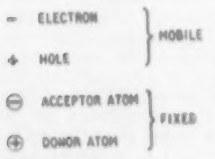


Fig. 4. Standard symbols for charged particles in semi-conductors.

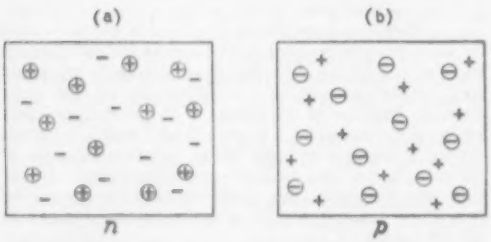


Fig. 5. Diagrams of (a) n-type and (b) p-type semi-conductor, using Fig. 4 symbols. Only the impurity atoms are shown; the atoms of germanium or silicon, which are usually millions of times more numerous, are omitted for clarity.

P-N Junctions

There is an important point to clear up before at long last getting to the uses of all this. It has probably occurred to you that impurities of *both* types would almost inevitably be present to at least the minute extent that is significant electrically; and what then? As one might guess, the opposite effects neutralize one another, so that if there are exactly equal quantities of opposite impurities the material behaves electrically as if it were pure; its conductivity is no more than the intrinsic conductivity of the material at that temperature. The neutralizing effect is called *compensation*. This might seem to be a short cut past the obvious difficulties of purifying anything to better than 1 part in 10^9. But if one were to try "purifying" germanium containing 1 part in 1,000 of arsenic—not very bad, by ordinary chemical standards—by adding an equal proportion of gallium, the problem of ensuring that the amount added was correct to 1 in a million might be worse than the problem being dodged. Anyway, in practice the germanium is purified in the proper straightforward way and the desired impurity added later; rather as crude iron is freed from carbon and then sufficient is added to make the grade of steel required. However, *over*-compensation is used to convert *n*-type to *p*-type or vice versa.

None of these three types of material—*n*, *p* or *i* (for "intrinsic")—is particularly useful on its own; it is when *n* and *p* types are brought closely into contact that results become really interesting. Just bringing two different pieces together is not good enough; in practice a single piece is caused to have *n* and *p* regions by introducing the appropriate impurities. The boundary between the regions—or often the whole combination of two kinds of material—is called a *p-n* junction.

The tendency of any concentration of electrons or holes is to scatter so as to fill the whole available solid uniformly. This movement is called diffusion, and is quite apart from movements caused by electric fields. So when the free electrons in the *n* half of a *p-n* junction look across the boundary and see the absence of electrons in the *p* half, they start drifting across. Similarly the holes in the *p* half start diffusing into the *n* region. Opposite charges moving in opposite directions are electric currents moving in the *same* direction—conventionally, the direction the positive charges (in this case, holes) move. However one looks at it, the *n* region, previously neutral, is becoming positively charged, and the *p* region negatively charged. The result is the growth of a potential difference between the regions. This p.d. tends to put a stop to the diffusion; the electrons that have

(*Continued on page 397*)

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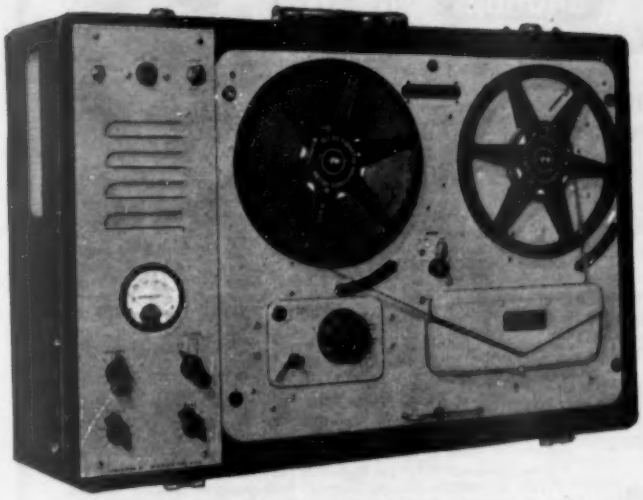

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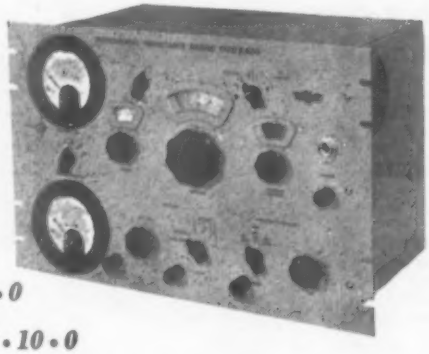

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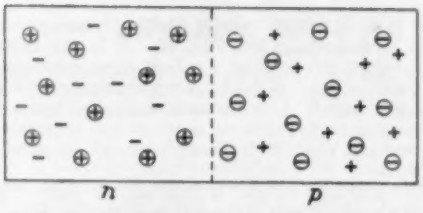


Fig. 6. A p-n junction, showing how the p side of the boundary becomes negatively charged because holes there are neutralized by electrons diffusing across from the n region. Similarly the n side becomes positively charged.

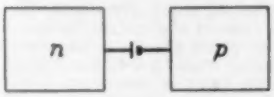


Fig. 7. The potential difference between the two sides of the boundary in Fig. 6 can be represented symbolically by an imaginary cell. But it must be realized that its voltage alters if an external e.m.f. is applied, as in Figs. 8 and 9.

already diffused, having no accompanying positive charges to neutralize them, form a negative charge that repels those coming on behind ("like charges repel"). Similarly with the holes.

Perhaps you think the trespassing electrons have plenty of positive charges around—a whole reservoir of holes—to neutralize them. But in so far as these holes combine with the electrons and cancel them out, they themselves are cancelled out and can no longer balance the acceptor atoms (which are fixed negative charges). So either way the diffusing electrons make the *p* region go negative. Similarly the diffusing holes make the *n* region positive. On the assumption that the diffusing bodies disappear by combining with their opposite numbers, the general effect can be represented as in Fig. 6. The charged atoms cause a positive excess on the *n* side of the boundary and a negative excess on the *p* side. When this p.d. is just enough to balance the tendency to diffuse, the process stops. The situation can be represented even more simply as in Fig. 7, the p.d. being indicated by an imaginary cell.

The Junction Rectifier

The next thing is to see what happens when an external e.m.f. is applied in the direction + to *n* and − to *p*, as in Fig. 8; that is to say, in series opposition to the imaginary e.m.f. in Fig. 7. This charges the *n* region still more positive by attracting more electrons out of it; similarly the *p* region is made more negative. And again, after a very small temporary flow of current a balance is reached in which there is no current (except for intrinsic conductivity, which we are still neglecting so as not to become confused by trying to take in more than one thing at a time). In the Fig. 7 style of diagram, the result would be represented by an increase in the number of imaginary cells, sufficient to balance the diffusion tendency plus the externally applied e.m.f.

Unlike either of the *n* or *p* pieces separately, the combination appears to be a non-conductor.

After a pause to tick off yet another piece of previously incomprehensible behaviour on the part of a semi-conductor, we reverse the battery. Its e.m.f. is now series-assisting the internal p.d., tending to make current flow. Electrons and holes trespass more or less freely on one another's regions; many of them annihilating one another no doubt, but the external battery replenishes the supply (Fig. 9). So in this direction current flows easily. The Fig. 7 "e.m.f." has meantime almost if not entirely disappeared, to represent the fact that the fixed junction charges shown in Fig. 6 are neutralized by the mobile charges.

In brief, a *p-n* junction is a rectifier.

According to the simplified theory just outlined, a *p-n* junction rectifier would be perfect—at least, in the reverse or no-current direction, because there really would be no current. How much resistance, if any, there would be to current in the forward direction does not appear. There would, presumably, be a bit of a bottom bend while the applied forward voltage was overcoming the junction p.d. indicated variously in Figs. 6 and 7, and after that the steepness would be greater the more the impurities present to contribute current carriers. The forward-current characteristic does in fact conform pretty well to that guess. It is the reverse behaviour that is more complicated.

First let us combine the impurity theory with the intrinsic theory. Then instead of Fig. 6, with nothing but donors and electrons on the *n* side and acceptors and holes on the *p* side, we would have to show a few heat-released electrons and holes on both sides. Some of the holes on the *n* side would no doubt be cancelled by electrons, which would be in a majority (they are, in fact, officially termed *majority carriers*, the holes being minority carriers), but those near the junction would find the p.d. there to be of the right polarity for carrying them across it to where they would be in a majority. Similarly, there would be a small current of electrons from *p* to *n*. This double current would tend to destroy

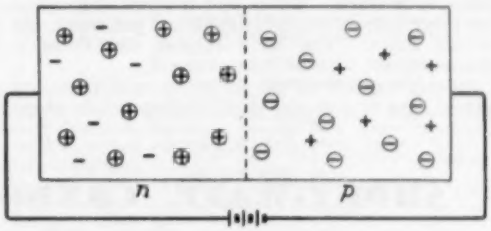


Fig. 8. An external e.m.f. of this polarity ("reverse") increases the p.d. shown in Figs. 6 and 7, and little or no current flows.

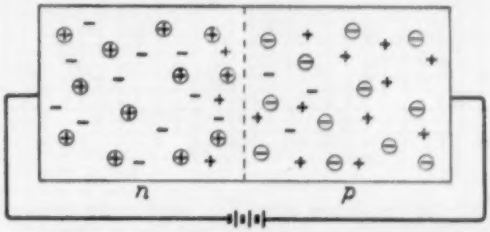


Fig. 9. An e.m.f. with "forward" polarity causes a relatively large current by enabling electrons and holes to flow freely across the junction.

the junction p.d., but if it did so the p.d. would be restored by diffusion. So instead of our previous picture of a balance with no current crossing the junction we have to substitute one with equal and opposite (and, at reasonable temperatures, relatively small) currents. Which for practical purposes comes to the same thing.

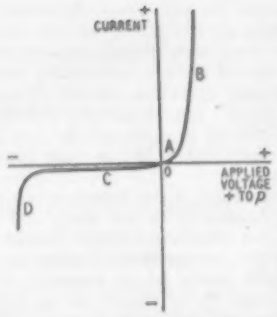


Fig. 10. Typical current/voltage characteristic of p-n junction.

When the reverse e.m.f. is applied (Fig. 8) the junction p.d. no longer depends for its existence on diffusion current, which comes to a stop. But the intrinsic current carries on regardless, for the p.d. actually assists the minority carriers across the frontier. Therefore there is some reverse current, not much affected by the amount of applied voltage once that has become sufficient to stop the diffusion current. This is an example of intrinsic conductivity being a nuisance. And, as we know, it increases with temperature, so if a germanium rectifier gets hot for any reason it may pass so much reverse current as to be useless for the purpose. Silicon, which requires greater heat energy to break up its co-valent bonds, is not so bad.

But that is not all. If the reverse e.m.f. continues to be raised a point is reached (sooner, if the proportion of impurities is large) at which the electric field strength due to it is sufficient to break up the co-valent bonds and release electrons and holes on a catastrophic scale. When that happens the crystal has practically no resistance at all and one says it has broken down. The large current that flows is known, by the way, as Zener current.

Putting together all the things we now know, we should have no difficulty in accounting for the shape of a *p-n* junction current/voltage characteristic, which is something like Fig. 10. A is the bottom bend, where the applied e.m.f. is busy overcoming the junction p.d. B is the steep current rise when it has succeeded. C is the nearly constant but small (if you are lucky) reverse current due to intrinsic conduction. And D is Zener current, plunging to its doom.

Still nothing about transistors, I fear. But Fleming's diode was soon followed by De Forest's triode, and history repeated itself after a fashion with semi-conductor devices.

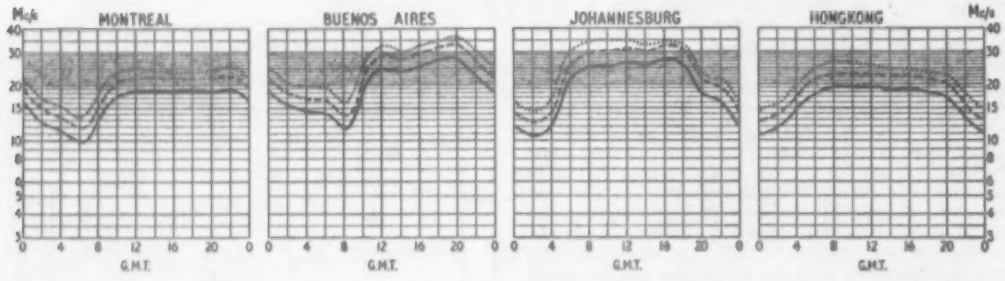
New Life for the "Personal" Portable?

THERE has always been a strong public demand for the small "personal" portable receiver and nothing is more certain than that many more would have been sold were it not for the fact that running costs have hitherto been high. Battery power in the form of miniature high-tension units is necessarily expensive—much more so than in the form of batteries made up of larger cells.

The obvious solution is to use transistors, which dispense with filament heating and can also be operated entirely from inexpensive low-tension cells. Already the transistor has ousted the valve in hearing aids, and at least one portable radio receiver has appeared with transistors in all its stages. This is quite an achievement as it is not so easy to match valve performance at high frequencies with the junction transistors.

Another solution, which has been adopted in the Grundig "200" portable, is to use valves for the r.f. and i.f. stages and transistors in the output stage. In any receiver the output stage accounts for the greater part of the power consumed and if this drain can be transferred from the h.t. to the l.t. battery, running costs are materially reduced. In the Grundig circuit the valve h.t. consumption totals only 3.5 mA from a 67.5-V battery. This is divided between the DK96 frequency changer (1.77 mA), DAF96 i.f. amplifier (1.07 mA) detector and 1st a.f. amplifier (0.055 mA) and DF97 driver (0.6 mA). In the output stage two OC72 transistors in push-pull require a standing quiescent current of 1.7 mA from the 6-V l.t. battery and an interesting feature is the use of a thermistor in parallel with one of the bias stabilizing resistors to help in compensating for changes in ambient temperature. The output stage would take about 15 to 20 mA on average music, and the filaments about 25 mA.

SHORT-WAVE CONDITIONS *Predictions for August*



THE full-line curves given here indicate the highest frequencies likely to be usable at any time of the day or night for reliable communications over four long-distance paths from this country during August.

Broken-line curves give the highest frequencies that will sustain a partial service throughout the same period.

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BOOKS RECEIVED

Color Television Receiver Practices. Edited by C. E. Dean. Based on a series of lectures given to visiting engineers by the Hazeltine Corporation (U.S.A.) covering basic concepts, the colour television signal, display devices, three-gun shadow-mask tubes, decoders, colour synchronization, i.f. and video amplificaation and test equipment. Includes selected references to the literature. Pp. 200+vii; Figs. 96. Price 36s. Chapman and Hall, 37, Essex Street, London, W.C.2.

Elements of Pulse Circuits, by F. J. M. Farley, M.A., Ph.D. Monograph, addressed to physicists and research workers with an elementary knowledge of radio valves and circuits, covering all the well-known pulse forming and amplifying circuits and explaining their action on a physical rather than a mathematical basis. The concluding chapter deals with applications in television, radar and nuclear research. Pp. 143+viii; Figs. 74. Price 8s 6d. Methuen and Co., Ltd., 36, Essex Street, London, W.C.2.

MK Buizen Handbook. International valve manual covering American and Continental types, in which the relevant information is displayed, for rapid reference, in circuit-diagram rather than tabular form. Quick access to sections on diodes, triodes, tetrodes and pentodes, output valves, frequency changers, combined valves, thyratrons, crystal diodes and transistors, and cathode-ray tubes is given by colour-coded pages. Pp. 334 with numerous diagrams. De Muiderkring, Bussum, Netherlands. British agents, The Modern Book Company, 19-23, Praed Street, London, W.2. Price 15s.

Definitions and Formulæ for Students—Modern Physics (3rd Edition). Compiled by L. R. B. Elton, Ph.D. Selection of memorable data including electronic and atomic constants, electron and field equations, the photoelectric effect, etc. Pp.+v. Price 2s. Sir Isaac Pitman and Sons, Ltd. Parker Street, London, W.C.2.

Contribuicao para o Estudo de Antenas Lineares—Teoria e Projecto de Antenas Rombicas by A. A. de Carvalho Fernandes, A.M.I.E.E., M.I.R.E. Comprehensive treatise (in Portuguese) on the theory of rhombic aerials, which includes formulæ for the intensity of the radiated field, taking into account components with both vertical and horizontal polarization. Practical data is given for the design of arrays of stacked, and stacked and interlaced rhombics. Pp. 415; Figs. 119. Price Esc. 150. Coimbra Editora, Lda., Avenida do Arnado, Coimbra, Portugal.

Studien über einkreisige Schwingungssysteme mit zeitlich veränderlichen Elementen by B. R. Gloor, Dr. Sc. Techn. An exhaustive study of the basic principles underlying the operation of super-regenerative receivers and an account of experimental work in verification of the theory. Pp. 234; Figs. 156. Price, Swiss Fr. 15. Verlag Leemann Zürich, Arbenzstrasse 20, Zürich 34.

Time-saving Network Calculations, by Harry Stockman, S.D. General advice on the approach to mathematical solutions of network problems with examples of the use of Thévenin's theorem, the potentiometer method and other techniques applied both for the transient and steady states. Pp. 120; Figs. 36. Price $1.75. SER Company, 543, Lexington Street, Waltham, Mass., U.S.A.

Abacs or Nomograms, by A. Giet. Written for engineers rather than mathematicians and shows how abacs for routine calculations may be constructed to correspond with formulæ involving any number of variables. Pp. 235; Figs. 152. Price 35s. Iliffe and Sons Ltd., Dorset House, Stamford Street, London, S.E.1.

Solution of Problems in Telecommunications, by C. S. Henson, B.Sc.(Eng.), A.C.G.I., A.M.I.E.E. Worked examples taken from papers of University of London B.Sc.(Eng.) and Graduate I.E.E. examinations to illustrate the application of basic theory to specific cases. Pp. 258+x; Figs. 122. Price 25s. Sir Isaac Pitman and Sons, Ltd., Parker Street, London, W.C.2.

Radio Electronics, by Samuel Seely, Ph.D. Mathematical analysis applied to the elements of communication systems and to the general problems of information theory and the effects of noise. Pp.487+vii; Figs. 438. Price 52s 6d. McGraw Hill Publishing Co., Ltd., 95, Farringdon Street, London, E.C.4.

Maintaining Hi Fi Equipment, by Joseph Marshall. Guide for service technicians to current American practice in high-quality sound reproducing systems, with practical hints on the tracing and elimination of distortion, hum, etc. Pp. 223; Figs. 135. Gernsback Library No. 58. Obtainable from Modern Book Company, 19-23, Praed Street, London, W.2. Price 23s.

Public Address and Sound Distribution Handbook. Advisory editor Alex. J. Walker. Description of amplifiers, microphones, loudspeakers, etc., used in p.a. work, and an analysis of typical complete installations. Pp. 160; Figs. 145. Price 21s. George Newnes, Ltd., Southampton Street, London, W.C.2.

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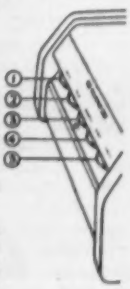

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RANDOM RADIATIONS

By "DIALLIST"

F.C.C. and Receiver Radiation

YOU may recall that I suggested a while ago that there couldn't be much interference radiated from the line timebase or otherwise by American television receivers, and that a Baltimore reader wrote that this was in fact the case. The position has now been cleared up by an article in the June number of *Radio-Electronics*, which describes a certification scheme for sound and vision broadcast receivers which is now being made compulsory by the F.C.C. This body, which has in some ways even greater powers than those given to our G.P.O. by the Wireless Telegraphy Act, regulates radio communications of all kinds, including broadcasting, in the United States. With the co-operation of most American radio manufacturers it has now brought out permissible radiation limits for receivers of every kind working on frequencies from 0.45 to 1,000 Mc/s. Every set sold after a certain date will have to be provided with "a distinctive seal or label" on which the manufacturer certifies that it complies with the F.C.C.'s radiation regulations. The scheme is progressive. The rule became applicable on May 1st this year to all kinds of v.h.f. receivers; u.h.f. sets put into production after December 31st must fall into line, and from the beginning of July next year no uncertified receiver of any kind may be offered for sale.

Can't We, Too?

The F.C.C. schedule of the maximum permissible field strength of the radiation by any receiver is the result of five years of close consultation between the U.S. government and industry. It is much to be hoped that something of the kind will be done in our country. It shouldn't take anything like five years, though, for much work has already been done and we have the American figures—the results of a vast amount of investigation and experimental work—to help us. If, for example, the maximum permissible field strength of receiver radiation between 25 and 70 Mc/s has been found in America to be 32 μV/m, that between 70 and 130 Mc/s to be 50 μV/m, and that between 174 and 260 Mc/s to be 50-150 μV/m, those figures should be suitable here for television and f.m. sets. There can be no great manufacturing difficulties about turning out receivers which comply with such limits, for the American radio industry has accepted them most enthusiastically. Couldn't some of our manufacturers give a voluntary lead by guaranteeing that their sets don't and won't interfere with other people's reception?

"Bournemouth Effect"

YOU remember the "Bournemouth Effect," which I recorded recently in these notes? A reader gave an f.m. receiver to his parents, then living in an apartment near the top of a large block of flats in Bournemouth. It worked perfectly; but when they moved later to a flat on a lower floor and the feeder was lengthened accordingly, he was told that they now heard the "chuffs" of every locomotive as it left the station. My best thanks to the many readers who wrote to me about this queer effect. All agree that the lengthening of the feeder provides the key to the problem. The increased attenuation brought signal strength down to a point at which the limiter was normally only just working; a very small further fall, whatever the cause, would put it temporarily out of action and produce the chuffing. Several letters suggest that aeroplane flutter may be responsible; but I understand that the noise occurred when a train was actually leaving. The clouds ejected from the funnel consist largely of steam and hot gases at high pressure. One correspondent suggests that these might give rise to an electrostatic effect and mentions that interference with v.h.f. reception has been noticed in launches driven by compression ignition engines.

Tough Luck

HOW easy it is, as things are, for the best of good citizens to become a nuisance to his neighbours is shown by a letter I've had from a Yorkshire reader, who lives in a semi-detached house. His hobby is wireless; he likes receiving distant stations and he has spent quite a lot of money on suitable receiving sets and aerials. Not long ago he began to suffer severely from unwanted noises and concluded that the receiving set, which he had had for some years, was packing up. Having bought a new one of a more sensitive type he was not a little surprised to find the unwelcome noises worse than ever; they were in fact strong enough to make

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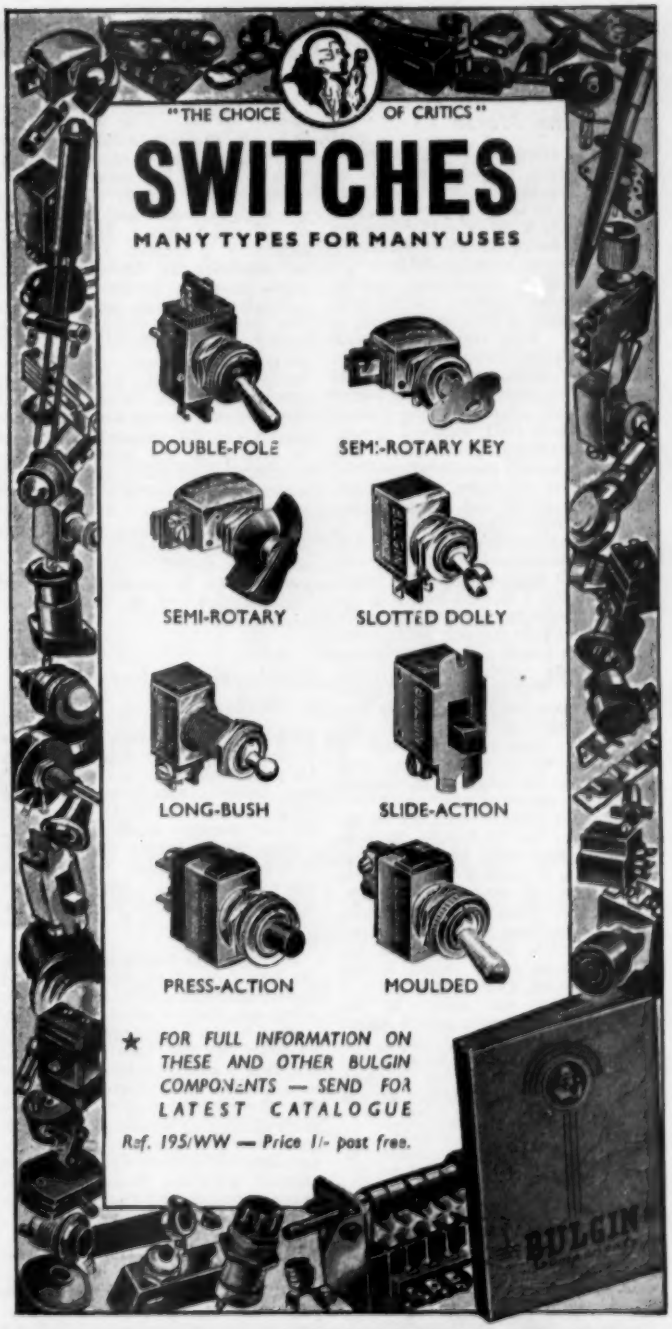
reception of any station but the local one quite impossible. He then discovered that the noises occurred only when the occupier of the other half of the "semi" was using his television receiver, an instrument of reputable make, bought in all good faith, and in good working order. The matter was reported to the G.P.O., but their engineers explained to my correspondent that they can't go into action unless interference spoils reception of the B.B.C.'s local station. And he couldn't honestly say that it did so.

Sunspots and Dx

DURING the next few months we shall probably reach the period of maximum activity in the present sunspot cycle. Spots and flares have already been responsible for some queer effects, including the big radio blackouts which occurred earlier this year. At or near previous maxima television reception has been recorded at times at almost uncanny distances. The Alexandra Palace transmissions were received on occasion in the United States, and, if I remember rightly, in South Africa. At the last sunspot maximum period there were few TV transmitters in action and receivers numbered only a tiny fraction of the present total; but during that period which we are now nearing when a huge number of transmitters will be in action and millions of receivers in use in different parts of the globe, I shouldn't be surprised if some remarkable Dx feats were recorded.

A Cry Over Spilt Milk

BEING one of those in favour of higher-definition television, I can't help feeling that it's perhaps a pity that we didn't decide to devote Band III entirely to 819-line television, clearing the whole of it from end to end and dividing the available channels between the B.B.C. and the I.T.A. The B.B.C. could have put on either its proposed second programme, or an 819-line version of its Band I transmissions. We'd have had vastly better television. We'll get that better television one day, of course; but there are so many snags in the way that it is not likely to come now until much water has flowed beneath the bridges. The French were luckier, as well as wiser. Very few 441-line receivers were in use when the 819-line system began to take shape and fate lent a hand a while ago when the 441-line station on the Eiffel Tower was burnt out.



UNBIASED

By FREE GRID

Mastering Morse

IT is not often that I omit to mention jubilees and centenaries of wireless landmarks but I am reminded by an article in the May issue of the *R.S.G.B. Bulletin* that I forgot all about the centenary of the international morse code in 1951.

This highly informative article points out that Morse's original code was compiled in 1837 and revised a year later. Both these codes used variable spacing between the elements of certain letter symbols but this practice was abandoned in the International code adopted by the Vienna Conference in 1851, and still in use.

An interesting point about the work of Morse is that he adopted the principles of what we now call information theory and arranged that letters in most frequent use—or in other words letters conveying the most information—should be given the shortest code symbols. He found that the letter E headed the list in the English language and so it was given the shortest code symbol. The Vienna Conference had to make compromises between the needs of the various languages. The letter O was apparently a stumbling block, being frequent in English but relatively infrequent in French and German. I wonder if the Polish delegate protested about the length of the symbol allotted for Z.

A curious point brought out by the author of the *R.S.G.B. Bulletin* article is that those learning morse get stuck at a speed of 7 to 10 words per minute. A writer in *W.W.* discussed this same problem fifteen years ago in June 1941 and I added a few remarks of my own in the October issue. He called it the "psychological pause," but differed slightly from the writer in the *R.S.G.B. Bulletin* as he gave a higher figure for it—about 15 w.p.m.

The real difference between the two writers, however, is in their remedies for overcoming this strange mental barrier. The writer in the *R.S.G.B. Bulletin* counsels perseverance or, in other words, hard work! Ugh! The *W.W.* writer gave a far more palatable remedy which was to get slightly drunk and he meant it in all seriousness. The effect of alcohol is to remove certain mental or psychological inhibitions which cause the speed barrier.

Similar tactics can be used to get over certain other brain and muscle co-ordination difficulties and it is possible for instance to dodge the drudgery of learning to type at high speed by the judicious use of alcohol. However, the system has never been adopted by the business colleges as, in certain of the more staid and reactionary City offices, girls who have learned to type rapidly in this manner are thought to be fast in more senses than one. I recollect once in my younger days dictating to a typist who—but there! readers of *W.W.* wouldn't be interested in personal reminiscences of a non-technical nature.

A morse miasma.

Triangular Television Wanted

TELEVISION screens seem to be getting bigger and bigger to cater for people who want to compete with the Jones's, for I cannot think people really want these big screens in the average small house. Big screens mean bigger cabinets with WX dimensions not only in the plane of the picture but in the fore and aft direction, too, as the tail end of the bigger C.R.T. has to be housed.

For the large family party I think the best type of set is one which I myself designed and built over three years ago for a Coronation viewing party at home. It was a console receiver modelled on the lines of Big Ben and had a moderate-sized screen on each of the four sides of the tower like the famous clock. Thus we were all able to sit round in a circle and view the long programme in comfort. The four tubes were all slightly different in their height above ground so that their tails didn't foul each other in the tower-like cabinet.

For ordinary family viewing I am at present using a set having two screens, one set at a slightly obtuse angle to the other so that each member of the family has a full-faced undisturbed view of the picture. This is much better than all crowding round a large screen with some people viewing the screen at an acute angle where they get an uncomfortable lop-sided view like the unfortunate rich people who patronize the boxes at a theatre. Here again, one tube is slightly higher than the other to avoid fouling of tails.

The ideal set for the ordinary man with a small family in a small house is one which will take up least room; namely, one with a triangular cabinet so that it will fit neatly into a corner. Why on earth some enterprising manufacturer doesn't produce such a set, I just don't know.

Car-Owners Corner

CERTAIN motoring experts seem recently to have discovered that cars which are, of course, insulated from the ground by their tyres acquire a static charge in dry weather which is said to cause car sickness. The result is that many dealers are selling small anti-static chains to trail behind cars.

It is no concern of mine, writing in a radio journal, whether static charges do or do not cause car sickness but I do know from experience that this trailing lightweight chain, owing to the poor connection it makes with the ground, causes intermittent discharge of the static charge and therefore bad interference with the car's radio set when receiving weak signals.

The real remedy is to earth the chassis so firmly that no static can even accumulate and this can be done by affixing to the tyres the chains sold for use on snowbound roads. This will undoubtedly attract the attention of the police and cause much licking of pencils, but it is not an offence. By the way, what has happened to the special anti-static tyres which were available in pre-war days when I last touched on this subject? (*W.W.*, 8.12.38.)

Tele-Pictures in 1842

WE are all so accustomed to seeing pictures in our newspapers which have been transmitted by radio that we are apt to take them for granted. Yet most people would laugh to scorn any suggestion that the telegraphic transmission of pictures dated back to Victorian or even Edwardian days; it is regarded as essentially a modern invention.

Yet the basic idea goes back not only to the days of Queen Victoria but to within five years of the death of William IV. It was in 1842 that Alexander Bain first proposed a scheme for transmitting pictures electrically, using two pendulums of identical dimensions as transmitter and receiver, respectively, for synchronizing purposes. Synchronization is the whole essence of picture transmission as it is of television, and this basic principle was realized by Bain. Thus picture telegraphy was conceived almost as early as ordinary telegraphy, but its period of gestation proved many decades longer.

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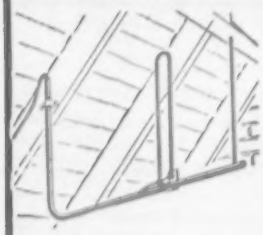
★ *Write for leaflet W* ★

H. J. LEAK & CO. LTD., BRUNEL ROAD, WESTWAY FACTORY ESTATE, ACTON, W.3

Phone: SHEpherd's Bush 1173/4/5 *Telegrams: Sinusoidal, Ealux, London* *Cables: Sinusoidal, London*

BAND III AERIALS



THE 'READY'

This is a ¼ wave-length, 3 element array. Of all alloy construction, the aerial is completely assembled and ready for instant mounting in loft, bedroom cupboard, window frame, etc. Price 12/6, plus 2/-.

3 element array with swan-neck mast with "U" bolt clamp for fitting to existing masts from ¾in. to 2in. dia.	41/6
3 element array with cranked mast and wall mounting bracket	42/6
3 element array with cranked mast and chimney lashing equipment	65/-
5 element array with swan-neck mast and "U" bolt clamp for fitting existing mast from ¾in. to 2in. dia.	52/6
5 element array with cranked mast and chimney lashing equipment	67/-
8 element array with swan-neck mast and "U" bolt lamp for fitting to ¾in. to 2i i. dia. mast	69/-

THE "CRISPIAN" BATTERY PORTABLE

A 4-valve truly portable battery set with very many good features as follows:—Ferrite rod aerials.

- **Low consumption valves.**
- **Superhet circuit with A.V.C.**
- **Ready built and aligned chassis if required.**
- **Beautiful two-tone cabinet.**
- **Guaranteed results on long and medium waves anywhere.**

All parts, including speaker and cabinet, are available separately or if all ordered together the price is £7/15/- complete. Post & insurance 3 6d. Ready built chassis 30/- extra. Instruction booklet free with parts or available separately price 1 6.

CAR STARTER CHARGER KIT

All parts to build 6- and 12-volt charger which can be connected to a "flat" battery and will enable the car to be started instantly. Kit comprising the following:—

Mains transformer	19/6
5-amp rectifier	17/6
Regulator stud Switch	3/6
Resistance Wire	2/-
Resistance Forms	2/6
Mains on/off Switch	1/-
0-5 amp. Moving Coil Meter	9/6
Constructional Data	1/6

or if bought all together price is 59/6, plus 3/6 post and packing.

CONNECTING WIRE

P.V.C. covered in 100ft. coils—most colours—four coils, different colours, 10/-, post free.

MINI-RADIO

Uses high-efficiency coils—covers long and medium wavebands and fits into the neat white or brown bakelite cabinet—limited quantity only. All the parts, including cabinet, valves, in fact, everything, £4/10/-, plus 3/6 post. Constructional data free with the parts, or available separately, 1/6.

MAINLY FOR EXPERIMENTS AND INDUSTRIAL USERS

VACUUM RELAY

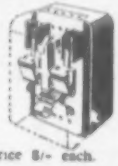
American made type No. C61610, this is a relay completely sealed in a glass envelope. It will close in a strong magnetic field or by a coil placed close to or round one of its arms. Price 49/6. Operating coils 25/- each.

WESTINGHOUSE (U.S.A.) METERS

All flush mounting type, outside diameter of face 3¼in.

0-500 v. D.C.	25/-
0-1.5 kV D.C. external multiplier	35/-
0-2.5 kV D.C. external multiplier	35/-
0-15 v. A.C. moving iron	30/-
0-1 mA.	25/-
0-50 mA	25/-
0-100 mA.	25/-
0-150 mA.	25/-
0-250mA	25/-
0-500 mA.	25/-

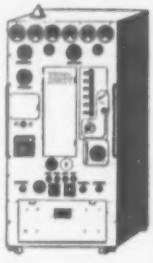
CONTACTOR



Solenoid operated—completely enclosed in cast-iron case, contacts rated at 7.5 amps D.C. —suitable for up to 30 amps. A.C. — coil volts 24 D.C. price 8/- each.

NAVY MODEL TCK-7

Seen at Eastbourne by appointment

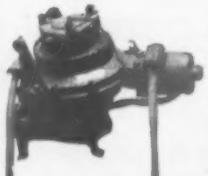


We have a few only American transmitters still in original packing cases. Designed for the Navy, these are really beautifully made and most impressive, standing 5ft. high by 2ft. wide and finished in instrument crackle. All meters and controls are on the front panel. The transmitter tunes over the range of 2 megacycles to 18 megacycles and it is designed for high speed precision communication without preliminary calling. Frequency control and stability is particularly good being better than .005% under the worst conditions. Power output is 400 watts on C.W and 100 watts on phone. Tuning is very simple—a unit control mechanism—gives a direct reading in frequency.

Complete with valves and instruction manual. Price £95. ex works.

NOTE.—The transmitter will work off A.C. or D.C. with the appropriate power unit. Power unit, are not available at present.

UNITS FOR CONTROLLED AUTOMATIC ROTATION



We have brand new, still in original unopened packing cases as shipped from America two items of equipment which form part of the radar system RC84. These two units work together to form a Tower rotating device with remote control.

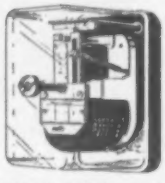
Item 1, known as Tower 24A, is in fact the geared driving motor which rotates the mast. This is quite a heavy construction and would rotate a heavy scanner, reflector, Beam array etc. etc.

Item 2, known as Indicator 1-221-A is the remote controller which enables the azimuth position of Tower 24A to be controlled from a remote point. Conversely it enables the azimuth position of the tower to be known at any time. Both the Tower and the Indicator contain selsyn transmitter/receivers and it is these that provide the impulses which cause the aerial to rotate backwards or forwards. The equipment intended for 117 volt A.C. mains but will operate from our mains if connected through step down transformer or 1 K.W. rating.

Price 1-221-A £25 plus carriage. TB24A £35 plus carriage.

Special discount of 5% for cash with order or C.O.D. if both units purchased together.

OVERCURRENT RELAY



Beautifully made by the famous American Westinghouse Company. These are the curious through panel type with clear Pyrex glass cover. They have coils for remote push button resetting.

Type A—calibrated for currents between .1 and 4 amps.

Type B—calibrated for currents between .5 and 2 amps.

Price, unused and perfect, £3/17/6 each.

RACKING EQUIPMENT

STANDARD OPEN RACK

6ft. high and 19in. wide, heavy steel construction. Holes drilled and tapped at the standardized spacings. Price £3/15/-, plus carriage.

MICA PANELS

Pure mica panels size 2in. x 3in. 3/- per dozen.

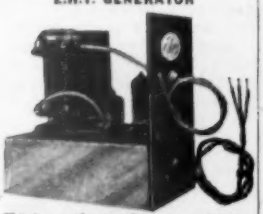
GRAMOPHONE AUTO-CHANGER

Latest types by all famous makers are invariably in stock at competitive prices. B.S.R., Monarch, Garrard, etc. Latest models from £7/18/6, plus 5/- carriage and insurance.

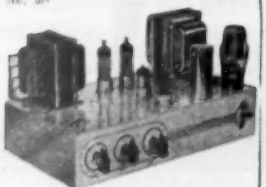
THIS IS ON OFFER AT APPROX. HALF COST TO MAKE

An impressive costly looking cabinet originally designed for T.V. but simple modification makes the cabinet suitable for radiogram, amplifier, tape recorder, or reflex speaker—size 23in. wide, 23in. deep and 37½in. high. Limited quantity at £8 15/- each, carriage 12/6.

E.H.T. GENERATOR



This is a made-up unit, power consumption 6.3 volt 5 amp, filament and approx. 50 mA. H.T. Contains three EY4 valves. Output from 6 kV to 9 kV rectified with normal H.T. rail input but somewhat higher outputs can be obtained with higher H.T. supply. Dimensions are 6½ × 4½ × 7in. Price 69/6, post, packing, etc. 5/-.



MULLARD AMPLIFIER "510"

A High quality Amplifier designed by Mullard engineers. Robust high fidelity with a power output exceeding 10 watts and a harmonic distortion less than .4% at 10 watts. Its frequency response is extremely wide and level being almost flat from 10 to 20,000 C.P.S.—three controls are provided and the whole unit is very suitable for use with the Collaro Studio and most other good pick-ups. The price of the unit completely made up and ready to work is £12/10/-, plus 10/- carriage and insurance. Alternatively, if you wish to make up the unit yourself we shall be glad to supply the components separately. Send for the Mullard amplifier blueprint 6d.

CABINETS FOR ALL

WE CARRY A VERY VARIED STOCK PLEASE CALL

The one illustrated is the "Empress," it is undoubtedly a beautiful piece of furniture. It is elegantly veneered externally in figured walnut, internally in white sycamore. The radio section is raised to convenient level but is not drilled or cut. The lower deck acts as the motor board, again is uncut, it measures 16 × 14 and has a clearance of 5in. from the lid. There is a compartment for the storage of recordings. Overall dimensions of this essentially modern cabinet are 3ft. wide, 2ft. 8in. high and 1ft. 4½in. deep. Price £14/14/-, carriage and insurance 20/-.

RECORD PLAYER FOR £4/10/-.

4-SPEED INDUCTION MOTOR

3-speed motor with metal turntable and rubber mat. Latest rim drive with speed selection by knob at the side

HI-FI PICK-UP

Using famous Cosmocord Hi-G turnover crystal. Separate sapphire for each speed. Neat bakelite case with simple adjuster for weight compensation

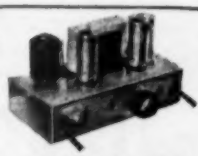
SPECIAL SNIP OFFER THIS MONTH

The two units for £4/10/-, or 30/- deposit and four payments of 18/-, post and insurance, 5/-. Or fitted upon base, as illustrated. £5 10/-, plus 7/6 post and insurance.

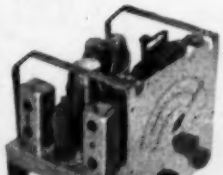
14" T.V. CABINET

14in T.V. cabinet of the latest styline made for one of our most famous firms—beautifully veneered and polished—limited quantity—19/6 each. Carriage and packing 3/6 extra.

The "ESTRONIC" BAND III CONVERTER



To-day's best value in Band III converters suitable for your T.V. or money refunded. Complete ready to operate. 59/6 non mains or 85/- mains, post and insurance. 3/6.



HALF-PRICE OFFER

BEETHOVEN CHASSIS

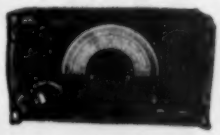
Extremely well built on chassis size approx. 9½ × 7½ × 8½, using only first-class components, fully aligned and tested. 110-240 volt A.C. mains operation. Three wave bands covering medium and two shorts. Complete with five valves, frequency changer, double diode triode, pentode output and full wave rectifier. Special cash-with-order price this month, £4 19/6, carriage and insurance 7/6. Polished cabinet, 49/6.

NEW CIRCUIT

OCCASIONAL 56—we have covered new T.R.F. circuit and have had really good results, equal to best of many superhets. You really should try this circuit. All parts including valves, 6K7, 6Q7, 6P9 and 6X5+ and Bakelite case with back cost only £5/10/- plus 2/6 post and insurance. Data included with the parts is also available separately price 2/-.

PLEASE INCLUDE POSTAGE WHEN ORDERING

R1155 YOURS FOR £2



The R1155 is considered to be one of the finest communication receivers available to-day. Its frequency range is 75 kc/s. to 18 Mc/s. It is complete with 10 valves and is fitted in a black metal case. Made for the R.A.F. as aforesaid a robust receiver which will give years of service. Completely overhauled and guaranteed in perfect working order. Price £2/19/6 or 3 payments of £1 each. Carriage and Transit case 15/- extra. Mains Power Pack with built-in speaker. £5/10/- or in perspex cabinet, £6/15/-.

OFFICE TELEPHONES

New G.P.O. telephones etc with Internal call and push button switch easily connected together to form office intercom. Price £2/10/- each. Post, etc., 2/6.

TRANSFORMER SNIP

11/6

Post 2/-

Multi-shrouded—standard 200-250 v. primary 250-0-250 at 80 mA. 6.3 v., at 3 amp. 5 v at 2 amp

FINE TUNERS

Ceramic trimmers all with ¼in. spindle of fair length. 5, 10, 15, 20, P.F. at 2/6 each or 24/- per dozen.

CIRCUIT DETAILS

Diagrams and other information extracted from official manuals. All 1/6 per copy 12 for 15/-.

American Service Sets	R.100
A.1134	70 receiver
BC.344	70 receiver
BC.312	R1116/A
R.103A	RA-16
R.C.344	AR88D
RA-1B	AN/ARA-1
R-409	70
R-1155	70
R-1134A	R.T.1½
R-1132A/R-148	CAV-46-AAM
R-1147	RADAR
R-1224A	A.R.B.-3
R-1082	Indicator 62A
R-1206	Indicator A.F.B.3
B.C.1306-A/B	Indicator 62
R-656-A (or -B	Indicator 6E
R-654-A (or -B)	R.F. unit 24
R-655-A (or -B)	R.F. unit 25
Transmitter T1154	R.F. unit 26
R.D.F.N.	R.F. unit 27
Fifty-mile walkie talkie	Wireless set No. 19 Osmetbed valves
Frequency meter BC 221	

ELECTRONIC PRECISION EQUIPMENT LTD.

249 Kilburn High Road Kilburn. Phone: MAI 4921 Half-day Thursday

42-46 Windmill Hill Ruislip Middlesex. Phone: RUISLIP 5780 Half-day Wednesday

152-153 Fleet St., E.C.4. Phone: FLEET 2833 Half-day Saturday

29 Stroud Green Road, Finsbury Park, N.4. Phone: ARCHWAY 1049 Half-day Thursday

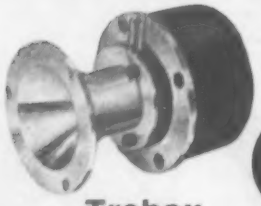
Post orders should be addressed to E.P.E. LTD., M.O. Dept. 2, 123, TERMINUS ROAD, EASTBOURNE.
All enquiries to Eastbourne address and please enclose S.A.E., terms are cash with order.

See them...hear them...

Stand No. 105 **Demonstration Room D. 7**

Goodmans

New Pressure Driven HIGH FIDELITY Reproducers



NEW PRODUCT

Trebax

A new high efficiency pressure driven reproducer covering the treble register from 2,500 c.p.s. to 16 k/cs.

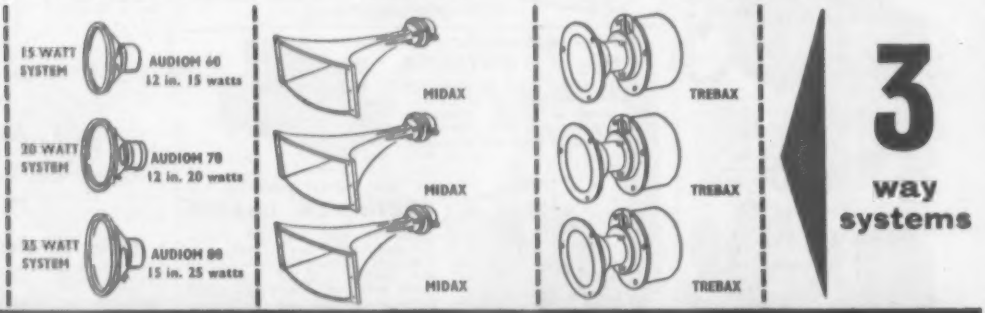
Used with the new MIDAX, the crossover point between these two units should not be below 4 k/cs. to allow for the "overlap" region. *(Impedance 15 ohms. at 10 k/cs.)*

NEW PRODUCT

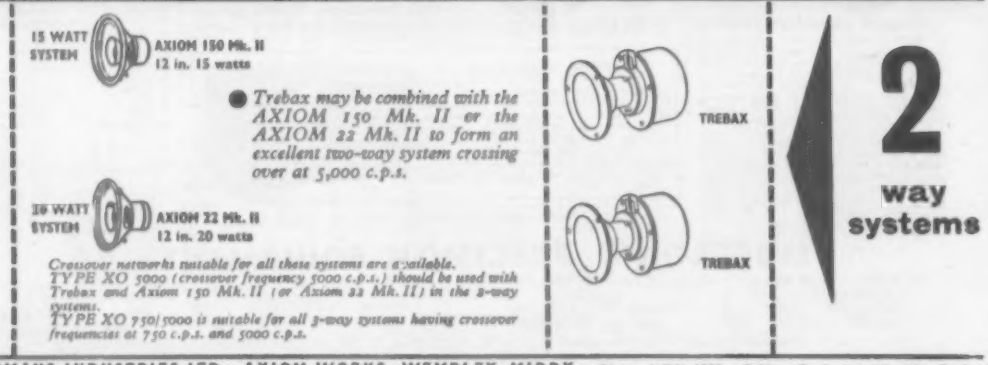
Midax

Horn-loaded mid-range pressure driven unit. (Frequency coverage 400 c.p.s. to 8 k/cs.)
When used in a 3-way system the crossover between Midax and the bass unit should be at 750 c.p.s. *(Impedance 15 ohms at 400 c.p.s.)*

● *These units combine to form outstanding 3-WAY SYSTEMS when used with an AUDIOM Loudspeaker fitted with a 35c.p.s. resonance cone.*



20 c.p.s. **to** 750 c.p.s. **to** 5000 c.p.s. **to** 16000 c.p.s.



● *Trebax may be combined with the AXIOM 150 Mk. II or the AXIOM 22 Mk. II to form an excellent two-way system crossing over at 5,000 c.p.s.*

Crossover networks suitable for all these systems are available.
TYPE XO 5000 (crossover frequency 5000 c.p.s.) should be used with Trebax and Axiom 150 Mk. II (or Axiom 22 Mk. II) in the 2-way systems.
TYPE XO 750/5000 is suitable for all 3-way systems having crossover frequencies at 750 c.p.s. and 5000 c.p.s.

GOODMANS INDUSTRIES LTD., AXIOM WORKS, WEMBLEY, MIDDX. *Phone: WEM 1200 Cables: Goodaxiom Wembley England*

at the Radio Show

Aug. 22nd to Sept. 1st

Goodmans

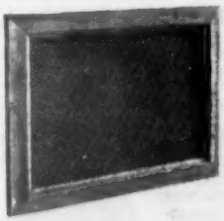
Axiom Full Range HIGH FIDELITY Loudspeakers

AXIOM 150 Mk.II
15 watts 12 in.
30–15,000 c.p.s.

AXIOM 22 Mk.II
20 watts 12 in.
30–15,000 c.p.s.

AXIOM 80
6 watts 9½ in.
20–20,000 c.p.s.

AXIETTE
6 watts 8 in.
40–15,000 c.p.s.

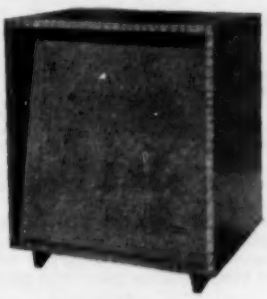


Acoustical Resistance Unit...

The Acoustical Resistance Unit *(illustrated)*, developed and manufactured exclusively by GOODMANS INDUSTRIES LTD., enables the cubic content of the Bass Reflex System to be reduced by one-third, while retaining full bass performance when used with Audiom or Axiom loudspeakers. *(Full dimensional drawings for enclosures supplied with all Audiom and Axiom loudspeakers).*

Axiom Enclosures...

Illustrated is a typical AXIOM Enclosure designed to incorporate GOODMANS LOUDSPEAKERS when used with an Acoustical Resistance Unit. Styling and shape of cabinet need only conform to the correct volume for any particular speaker system. Overall size is two-thirds that of an equivalent Bass Reflex Chamber. The bass response of the AXIOM or AUDIOM Loudspeaker, when used in these cabinets, is extended down to 20 c.p.s. No objectionable resonances occur above this frequency. Air loading of the loudspeaker cone is fully maintained to zero frequency, reducing harmonic and intermodulation distortion due to excessive cone displacement.



tickets?

See Goodmans Loudspeakers at Stand No. 105... hear them in Demonstration Room D.7. Daily Demonstrations throughout the show every half-hour. Tickets available on the Stand. Avoid disappointment by posting the coupon, indicating preference of day and time. Tickets for SATURDAYS only available at the Stand on the day.

TO: GOODMANS INDUSTRIES, LTD., AXIOM WORKS, WEMBLEY, MIDDX.

Please send ..... tickets for your demonstration

at ..... a.m./p.m. on ..... (date)

OR at ..... a.m./p.m. on ..... (date)

Name .....

Address .....

WW856

Scottish Distributors: **LAND SPEIGHT & COMPANY, LIMITED, 2 FITZROY PLACE, SAUCHIEHALL STREET, GLASGOW**

MULTITONE

SPECIALIZE
in equipment for the DEAF
and for PHYSIOTHERAPY

The ADAPHONE

enables the deaf to hear TV and Radio programmes in comfort and safety and with a clarity unobtainable when using a hearing aid for this purpose. It is also ideal for those with normal hearing who wish to hear the programmes without disturbing others.

The Adaphone has an attractive grey plastic case (3in. x 2in. x 1¼in.). Weighted straps hold it in position on any chair arm. The input is matched for 2 to 10 ohms connection and the transformer tested to withstand 2,000 volts D.C. The listener can adjust the volume to his individual need without affecting the loudspeaker volume.

Tone control is obtained by alternative output sockets; 'Normal' and 'High.'

The M3 model has Automatic Volume Compression.

A low-impedance insert-type magnetic miniature receiver of D.C. resistance 30-40 ohms is supplied, but a bone-conduction receiver is available instead, at extra cost, for those who prefer it.

MODEL M4. Complete with miniature ear piece, standard earmould, and leads	£4 19 0
MODEL M3. Incorporating Automatic Volume Compression, complete as above	£5 15 0
MODEL M5. Incorporating Loudspeaker Switch for "silent" listening	£5 15 0

Obtainable through all leading Radio Dealers or direct from Multitone Electric Company Limited.

Enquiries should be addressed to
MULTITONE ELECTRIC CO. LTD.
12/20 Underwood Street, London, N.1.
PIONEERS IN SOUND AMPLIFICATION

L·R·S
Estd. 1925
EASY TERMS

LEAK QUALITY EQUIPMENT
for the Connoisseur

If you want the Finest Quality Reproduction together with Workmanship of the Highest Order your choice must be **LEAK.**

AS USED BY BROADCASTING CORPORATIONS THROUGHOUT THE WORLD.

LEAK "TL/10" AND "POINT ONE" PRE-AMPLIFIER. Cash Price £28/7/-, or sent for £4/10/- Deposit and 18 monthly payments of 30/-, carr. and crate free.

LEAK DYNAMIC PICK-UP
Complete with two detachable diamond heads and transformer. **Cash Price £21/19/9** or sent for £4 Deposit and 10 monthly payments of 43/-. Post and packing paid.

Delivery of all the above is from stock. We can also supply the **LEAK F.M. TUNER.** Wharfedale, Goodmans and Tannoy loudspeakers, etc., Connoisseur Variable 3-speed Motors and all other Quality Equipment on EASY TERMS. *Please send us your requirements. Quotation by return of post.*

The L·R·SUPPLY COMPANY, LTD.
SALCOMBE (Tel. 254) SUssex.

. . . 19,801 contacts (as shown) soldered in one working week with the new ORYX model 18 soldering iron. For rapid soldering on your production assembly line without fatigue. Patented construction ensures maximum efficiency. Send for leaflet or a sample on sale or return and try for yourself. ORYX for reliability, for efficiency, for comfort, economy, safety, speed.

ORYX
MODEL 18
SOLDERING INSTRUMENT
6-6.3 v. 18 WATTS
7½" LONG. WEIGHT 1 oz.
BIT SIZE 3/16". LIST PR. 35/-
3 TOWER HILL **ANTEX** LONDON, E.C.3

Direct readings of

FREQUENCY

TIME

PERIOD

New (hp) 523B

ELECTRONIC COUNTER

- Extreme dependability
- Etched, unitized circuits
- Permits viewing time-interval start and stop points on oscilloscope
- High accuracy crystal oscillator circuit
- Trouble-localizer lights
- Counts pulses of selected voltage level

Construction of the new *-hp-* 523B is highest quality throughout. Etched circuits are rugged, ultra-dependable. Circuits are arranged for complete visibility. Trouble-localizer lights and plugs disconnecting circuit elements further simplify mainteance.

Exclusive features include a pulse output for oscilloscope Z-axis modulation permitting visual identification of the time-interval start and stop points on the input waveform measured. There is also a pulse count discriminator counting only pulses of voltage above a pre-determined level; and a high accuracy, high stability crystal controlled oscillator. Controls are color-coded, concentric, functionally arranged. Readings are direct in clear, bright numerals; decimal is automatic and illuminated.

The broad range and versatile usefulness of *-hp-* 523B is indicated by the Specifications at right. Model 523B is designed for utmost speed and simplicity in measuring production quantities, rpm, nuclear pulses, power line frequences, repetition rates, time intervals, pulse lengths, shutter speeds, velocities, relay times, frequency ratios, phase delay, etc.

10 cps to 1.1 MC!

With transducers, *-hp-* 523B also provides local or remote measurement of weight, pressure, temperature, acceleration, etc.

BRIEF SPECIFICATIONS

FREQUENCY MEASUREMENT:

Range:	10 cps to 1.1 MC
Accuracy:	±1 count ± crystal stability
Input Minimum:	0.2 v RMS
Input Impedance:	Approx. 1 megohm, 30 μμf shunt
Gate Time:	0.001, 0.01, 0.1, 1, 10 seconds
Reads Directly In:	KC. Automatic decimal

PERIOD MEASUREMENT:

Range:	0.00001 cps to 10 KC
Accuracy:	±0.3% (1 period); ±0.03% (10 periods)
Input Minimum:	1 v RMS
Input Impedance:	Approx. 1 megohm, 40 μμf shunt
Gate Time:	1 or 10 cycles of unknown
Standard Counting:	10 cps, 1 KC, 100 KC, 1 MC, External
Reads Directly In:	Sec, msec, μsec; automatic decimal

TIME INTERVAL MEASUREMENT:

Range:	3.0 μsec to 100,000 sec (27.8 hrs)
Accuracy:	±1 std. freq. counted ± stability
Input Minimum:	1 v peak. dc coupled
Input Impedance:	Approx. 1 megohm, 25 μμf shunt
Trigger Slope:	Pos. or neg. on start/stop independent or common channels
Trigger Amplitude:	−300 to +300 v adjustable
Standard Counting:	10 cps, 1 KC, 100 KC, 1 MC, External
Reads Directly In:	Sec, msec, μsec, automatic decimal

STABILITY: 2/1,000,000 per week. Also WWV

DISPLAY TIME: Variable 0.1 to 5 sec, or indefinite

OUTPUTS: Secondary standard: 10 cps, 1 KC rectangular, 100 KC, 1 MC sine wave.

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Finish: **Dark Battleship grey**

SPECIFICATION

SUPPLY: With A.C. Power Pack (CT52)—100/125 volts 50/60 c/s. With D.C. Power Pack (CT84)—28 volts D.C. Power consumption 50 VA approx.

CATHODE RAY TUBE: Hard tube—2¾in. diameter screen. Standard tube fitted has Green screen with medium afterglow Alternative tubes can be fitted.

TIME BASE: Free-running linear time base, paraphrase amplifier and synchronising. Repetition range 10 c/s. to 40 Kc/s. Single-sweep linear time base with paraphrase amplifier, triggered by 30-volt pulse. Repetition range—50 c/s to 3,000 c/s. Sweep range—50 milliseconds to 3 microseconds.

Y PLATE ATTENUATOR: Resistance Attenuator, capacitance compensated. Flat response—3 db from D.C. to 100 kc/s. Fixed attenuation of 14 db (5 times).

Y PLATE CONNECTION: Direct or series capacitor connection.
Input resistance—2.5 megohms. Input capacitance—50 pf. approx.

Y PLATE AMPLIFIER: 1. Max. gain of 33 db. (80 times) flat to 3 db. from 25 c/s. to 150 Kc/s.
2. Max. gain of 28 db (25 times) flat to 3 db. from 25 c/s to 1 Mc/s.

CALIBRATION: An internal supply of 50-volt peak ± 10%, sine wave, at the supply or vibrator frequency.

DELAY LINE: A delay network brought to the Y plate switch, and the displayed signal is delayed by approximately 0.5 microseconds, provided that its source impedance is of the order of 75 ohms.

RATING: Continuous operation at ambient temperatures between 32° C. and + 50° C.

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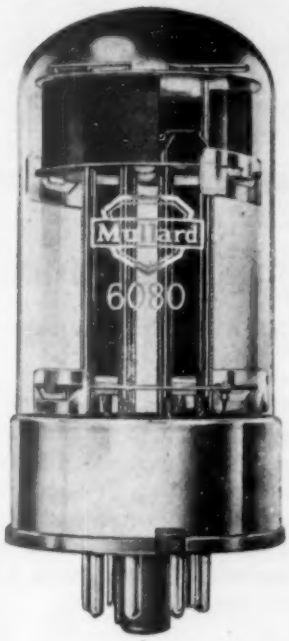

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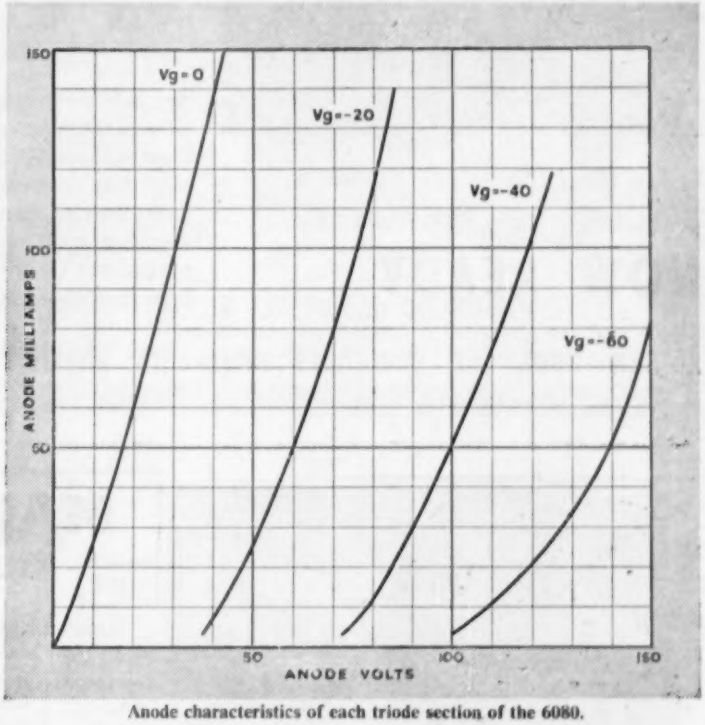

Anode characteristics of each triode section of the 6080.

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Abridged data for each triode section

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μ 2.0	r_a 280 ohms	$p_a$max 13 watts

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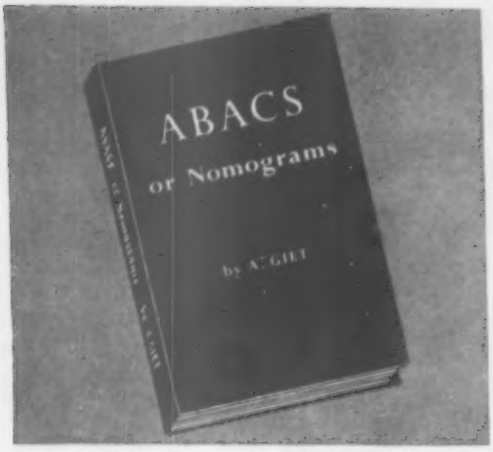

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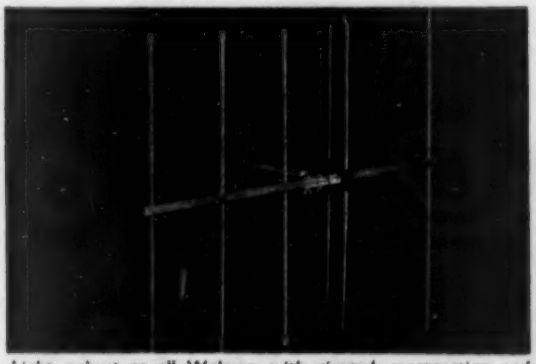

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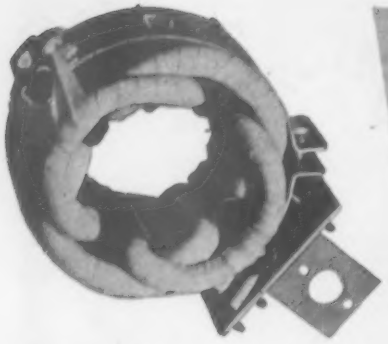

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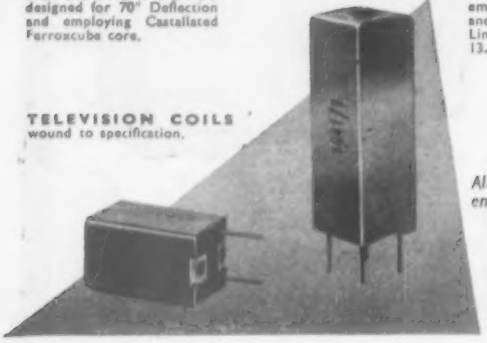

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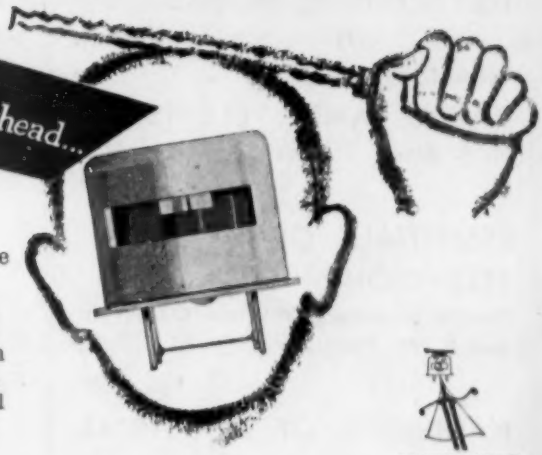

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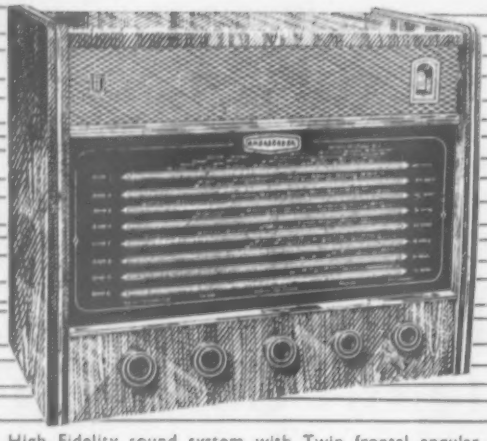

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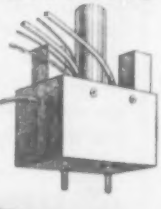

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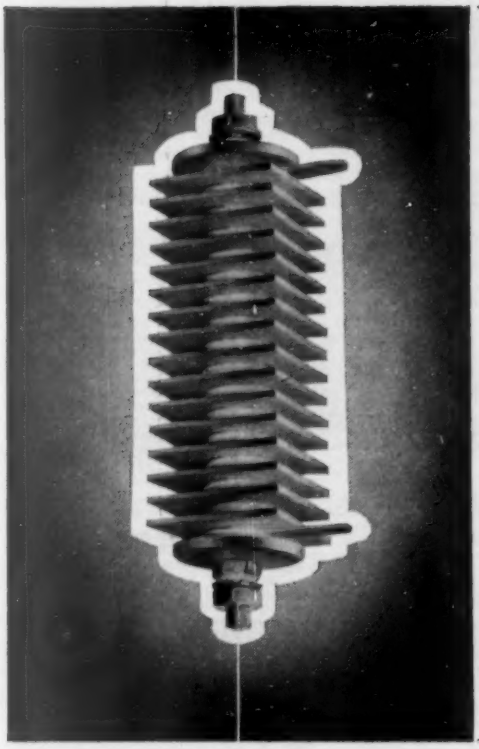

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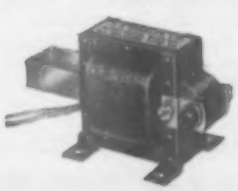

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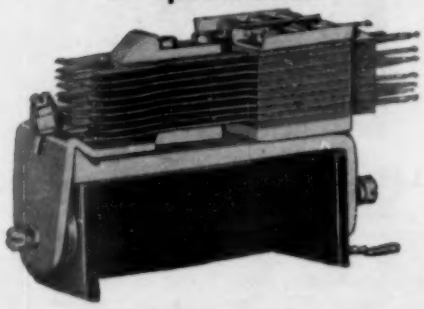

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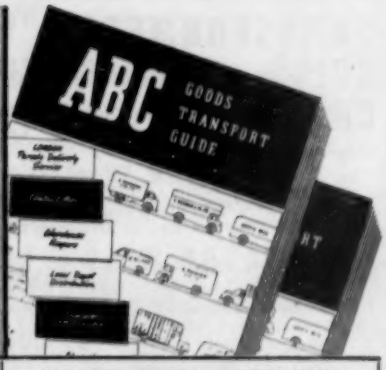

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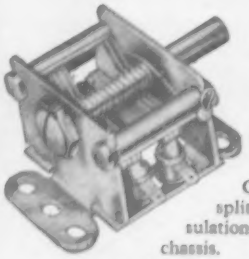

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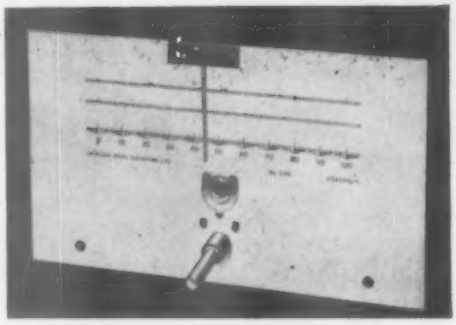

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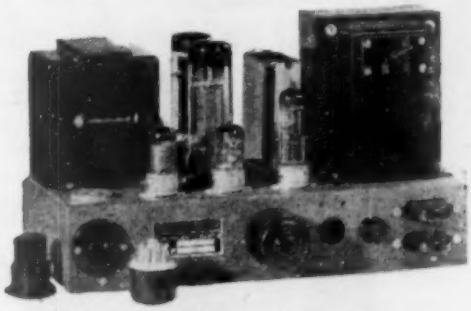

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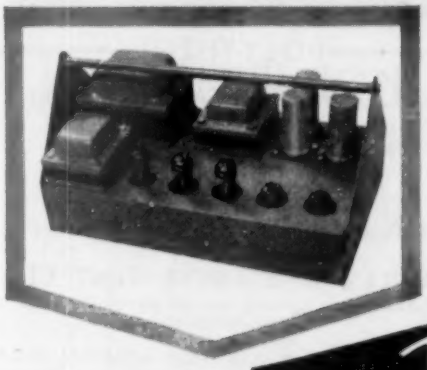

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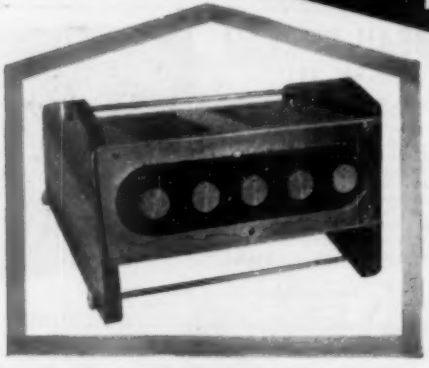

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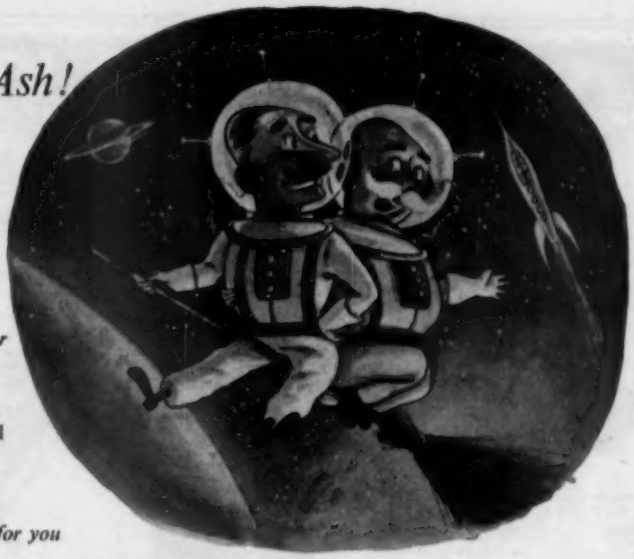

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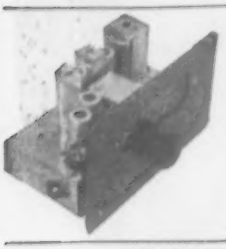

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THE T.S.I. AM/FM CHASSIS! Exceptional value. Covers L.M. and S.W. plus F.M.! 8-valve push-pull output. Ferrite rod aerial. Valve line-up: ECC85, ECH81, EF89, EABC80, ECC82, two 6BW6s plus 5y3. Large full-vision dial, size 14¼ × 6in. Chassis size, overall: 15 × 7½ × 8in. high. Tax paid 26 guineas, plus 5/- packing and carriage. A supplementary extra is magic eye EM34, complete with escutcheon and fixing cable at 29/-. H.P. terms available. Demonstrations at 18 Tottenham Court Road!

THE DULCI F.M. TUNER. Incorporates own power supply, suitable for use with any amplifier. Valve line-up: ECC85, two EF89, EABC80, 6 × 4, and EM80 indicator! Overall size: 9 × 6 × 6½in. high. Pre-Budget price £16/16/- plus 5/-. P.P. Illustrated leaflet available, also H.P. terms.

SPECIAL OFFER!! Champion Model 835 FM/VHF Adaptor! Designed for the instant conversion of A.C. radiograms, table A.M. receivers and Hi-Fi audio amplifiers, to enable owners through their existing equipment to obtain the best results from the new F.M. transmission. Two connections only. One to the A.C. mains supply, the other to the pick-up sockets. Valve line-up: EF85, two EF80s, EB91, and EZ80. In attractive red and cream bakelite cabinet. Illustrated leaflet available on request. Price whilst stocks last only £15/19/6 tax paid, plus 3/6 P. & P. H.P. terms available.

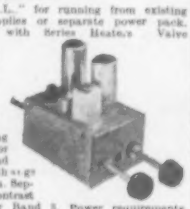
DENCO F.M. TUNER. This highly successful kit is still available at inclusive price of £6/7/6 plus 2/6 P. & P. This kit includes all components and the five valves required for the extra I.F. stage for fringe area reception. If required, "Denco" dial and drive assembly is available for the above at 5/- extra. Full constructional details 1/6 post free.

F.M. POWER PACK KIT. We can now supply complete kit for power pack suitable for the above F.M. tuners or any other similar type. Price for the complete kit is 37/6 only, or 52/6 for ready assembled unit. This pack is extremely small, incorporating valve rectifier type 6X4 and built on chassis size only 6 × 4 × 1½in. Optional extra for power pack. Bulgin Octal Plug 2/3.

THE K.L.F. 5-VALVE RECEIVER. All dry battery operation, for use with headphones. The complete kit is available at 42/-, less batteries, plus 2/- P. & P., or full instructions at 9d. post free.

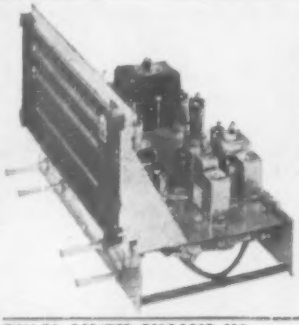
COMPETITIVE!! BAND III. CONVERTORS!

Type "M.L." for running from existing power supplies or separate power pack. Available with Series Heaters. Valve line-up: PCC84 and PCF80. Size 4 × 3½ × 4¼in. Fitted with external fine tuning control for Band 3 and Band 1/3 change over switch. Separate contrast control for Band 3. Power requirements H.T. 150/250 v. at 36 mA., L.T. 15/16 v. .3 amp. (Series Heaters). Unit simply fitted inside cabinet. Complete with sandsome escutcheon. Available for A.C. operation with parallel heaters, ECC84 and ECF80 as above. Price £4/12/6. P. & P. 2/6. Full instructions supplied with each unit. Please specify whether for London, or Birmingham, or Manchester.



THE FAMOUS UNIVERTER—COMPARE THE PRICE

Handsome walnut cabinet. Suitable all areas. Contains own power supply. Simply connect to aerial. Four-valve circuit. Complete with all instructions £6/19/6 plus 3/6 P. & P.



AM/FM RADIOGRAM CHASSIS! BARGAIN!

A special purchase of strictly limited quantity enables us to offer the following! For Medium, Long and F.M. Wavebands, plus gram position . . . Chassis size overall 13½in. long, 9in. high, 7½in. deep. Dial which is attractive red, green and gold lettering, on black background, measures 12in. × 5½in. horizontal. For A.C. mains, 200/250 v. Valve line-up ELA4, EABC80, EF86, ECH81, ECC85, EZ80, plus EM80 Magic Eye!! Limited quantity at bargain price of £18/19/6 only, plus 5/- P. & P. H.P. terms.

DULCI AM/FM CHASSIS H4

Illustrated leaflet available. L.M. and Short Waves plus F.M. This is a quality chassis 6 latest B.V.A. Mullard Valves, including magic eye. High Q. Inductances throughout, also Ferrite rods. Price to £27/16/- cash—or H.P. terms.

DULCI AM/FM TUNER

Just released. Details available. Price £24 including tax, or H.P. terms.

AM/FM KIT! FIRST AGAIN!

Introducing the JASON AM/FM KIT for medium waves and F.M.!
As illustrated this is a very high quality chassis incorporating 8 of the latest miniature valves, plus DM70 magic eye. Kits are available for chassis complete with output stage at £15/5/-. Also less output stage but with own built-in power pack at £13/19/6 only. These are high fidelity units and exceptional value at these prices which include all required components and full constructional details. Fully illustrated Data Booklet with full construction details, plus individually priced component list, available per return of post at 2/- post free. Both plus 3/6 P. & P.

SPECIAL PURCHASE! MANUFACTURER'S SURPLUS

Owing to favourable purchase, we can offer strictly limited quantity of these handsome chassis. AC/DC 200/250 v. for Medium and Long Waves, plus gram position. Incorporates own frame aerial. Valve line-up: U107, N108, DH107, W107 and X109. Overall chassis size 15 × 8½ × 7½in. high. Attractive bronze dial with gold and cream lettering. Dial size 11½ × 4½in. Scale length 7½in. Logging scale provided. Price £7/19/6 only, tax paid, plus 2/6 P. & P. H.P terms. £4 deposit plus four monthly payments of 22/-.

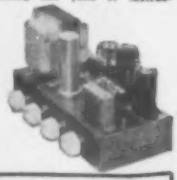
THE R.C. GRAM REPLACEMENT CHASSIS KIT.

Still available. Our very popular Gram Chassis replacement kit. For long, medium and short waves, and provision for gram. Valves 6K8, 6K7, 6Q7, 6V6 and 6X5.

For A.C. Mains 200/250 v. Chassis size: 13½in. × 5½in. × 2½in. Dial size 10½ × 4½in. Assembly is simplified by use of ready assembled coil pack. Illustrated booklet with full assembly instructions, with itemised price list, is 1/6 post free—or the kit complete to incl. nut and bolt at £3/9/- plus 2/6 P. & P.

THE R.C.2/4 WATT AMPLIFIER KIT.

Just released! Compare the advantages! Treble bass, AND middle controls! For crystal or magnetic pickup! A.C. Mains 200/250 v. Valve line-up, 6V6GT, 6SQ7, metal 6X5GT. Negative feedback. Built on stove enamelled steel chassis, measuring only 8in. × 6in. × 1½in. Four engraved cream knobs are included in the price of the complete kit with all necessary practical and theoretical diagrams, at £4/5/- only, plus 2/6 packing and post, or Instruction Book fully illustrated, for 1/-. Post free! This amplifier can be supplied assembled, tested, and ready for use at £5/5/- plus p. and p. Hearing is believing.

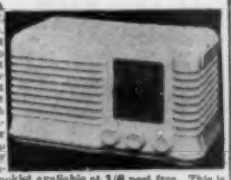


ACOS TYPE 7 Crystal Microphone inserts. Brand new. 7/6 each, post free

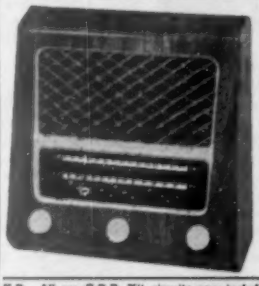
Our advantageous H.P. terms are available on any single item over £5. Let us have your enquiries.

Please add postage under £1, or Cash with order. C.O.D. charge extra—open 9 a.m. to 6 p.m. Monday to Friday. Sorry but we close 1 p.m. on Saturday.

THE "ECONOMY FOUR" T.R.F. KIT. A three-valve pine metal rectifier receiver. A.C. mains 200/250 v. Medium and Long waves. We can supply all required components right down to the last nut and bolt. Valve line-up 6K7, 6J7 and 6V6. Chassis ready drilled—Cabinet size 12in. long by 6in. high by 5in. deep—Choice of ivory or brown Bakelite, or wooden walnut finish cabinet. Complete instruction booklet with practical and theoretical diagrams. Each component brand new and tested prior to packing. Our price **25/10/-** complete—Remember this set is being demonstrated at our shop premises. We proudly claim that our fully illustrated instruction booklet is the most comprehensive available for this type of receiver—Booklet available at **1/6** post free. This is allowed if kit is purchased later. Plus 2/6 packing and carriage for complete kit.



THE "SUPERIOR" FOUR KIT. Our new four-valve receiver. A.C. mains, 200/250 v. M. and Long waves. As with our very successful "Economy Four" all required components are supplied. Valve line-up: 2 6BG7, 6 X5GT and 6 V6GT. Chassis ready drilled. Cabinet size, 10½in. × 10in. wide. Maximum depth at base 5in. tapering to 3½in. at top. Sloping front. Very attractively finished in light walnut and peach. Each component brand new and tested prior to packing. Complete instruction booklet with practical and theoretical diagrams is provided. Booklet available at **1/6** post free. Our price for complete kit, **£6/9/6**. Please add 2/6 packing and carriage. If preferred, we can supply Cabinet Assembly only, comprising Cabinet and bracket wave-change switch, dial, pointer, drum pulleys, drive spindle, drive spring and knobs, at **45/-**, plus 2/6 packing and carriage. **N.B.**—Our kits are even supplied with sufficient solder for the job.



N.B. All our T.R.F. Kit circuits now include specially wound Denco "Maxi-Q" coils on polystyrene formers, improved performance! Price remains the same.

SURPLUS BARGAINS

METERS

	Size	Type	Fitting	Price
F.S.D.				
50 microamps	D.C. 2in.	M.C.	F.R.	50/-
50 microamp	D.C. 3½in.	M.C.	F.R. (Tropicalised)	95/-
50 microamp	D.C. 5in.	M.C.	Rectangular	130/-
50 microamp	D.C. 4in.	M.C.	Rectangular	110/-
50 microamp	D.C. 3½in.	M.C.	F.R.	95/-
100 microamp	D.C. 2½in.	M.C.	F.R.	45/-
200 microamp	D.C. 2in.	M.C.	F.R. (Tropicalised)	45/-
200 microamp	D.C. 3½in.	M.C.	F.R.	65/-
500 microamp	D.C. 2in.	M.C.	F.R.	18/6
1 mA.	D.C. 2in.	M.C.	F.R.	17/6
1 mA.	D.C. 2in.	M.C.	F.Sq.	22/6
1 mA.	D.C. 2in.	M.C.	F. Sq. (1934 manufacture by Elliott)	95/-
1 mA.	D.C. 2½in.	M.C.	Desk Type	30/-
5 mA.	D.C. 2in.	M.C.	F. Sq.	10/-
50 mA.	D.C. 2in.	M.C.	F. Sq.	8/6
150 mA.	D.C. 2in.	M.C.	F. Sq.	7/6
500 mA.	D.C. 2½in.	M.C.	F.R.	10/-
.5 amp.	R.F. 2in.	Thermo	F. Sq.	6/6
1 amp.	R.F. 2½in.	M.C.	F.R.	10/-
120-0-120 amp.	D.C. 2in.	M.C.	F. Sq. (shunt required)	15/-
150 amp.	A.C. 4in.	M.I.	R.P.	45/-
1 amp.	R.F. 2½in.	Thermo	R.P.	7/6
3 amp.	R.F. 2in.	Thermo	F. Sq.	6/-
5 amp.	D.C. 2in.	M.C.	F. Sq.	13/6
20 amp.	D.C. 2in.	—	R.P. (with shunt)	10/6
25 amp.	D.C. 2½in.	M.I.	F.R.	6/6
30 amp.	D.C. 2½in.	M.I.	F.R.	12/6
15 volt	A.C. 2½in.	M.I.	F.R.	10/-
20 volt (5 mA.)	D.C. 2in.	M.C.	F. Sq.	7/6
15-0-15 volt	D.C. 2½in.	M.C.	F.R.	17/6
300 volt	A.C. 2½in.	M.I.	F.R.	35/-
300 volt	A.C. 3½in.	M.I.	F.R.	30/-

3½in. ROUND FLUSH MOUNTING METER by WESTON, blank scale ready for re-engraving, FSD 650 microamps, brand new, **27/6** only.

SPECIAL. U.S. 0-1 mA. 2½in. taken from equipment but perfect. **22/6** each. R.P. = Round Projection. M.C. = Moving Coil. Thermo = Thermo-coupled. F. Sq. = Flush Square. F.R. = Flush Round. M.I. = Moving Iron.

METER RECTIFIERS, 1 mA. by G.E.C., at **6/6**, also 5 mA. by G.E.C., at **6/6**.

COMMUNICATION RECEIVER PCR.2 3-wave band, 13-50, 190-570, 900-2,000 metres. Valve line-up 6V6, EBC33, X61 and 3-EF.39. Illuminated calibrated dial, fly-wheel tuning, aerial trimmer. In black crackle case size 17½in. × 16in. × 9in. Output socket for 3 ohm speaker, or headphones. Absolutely brand new in original cartons, manufactured for Govt. by PYE LTD.

Price **£7/10/-** only, plus p. and p. 10/-. With each set we supply full conversion details for A.C. mains. All required components for conversion available at **32/6** post paid. Limited quantity.

We can now supply already converted ready for A.C. Mains at **£9/19/6**, plus carriage. H.P. available.

METER SPECIAL! We have a limited quantity of aircraft electrical thermometers. Brand new, by Weston. 2in. moving coil meter, flush square fitting. These meters have a luminous scale graduated 40-140 degrees centigrade, but the full scale deflection is approximately 150 microamps. Price **12/6** each only, plus 1/- P. & P.

VIBRATOR PACK. Brand new, by Mallory 12 volt input, 150 v. 40 mA. output. Complete with synchronous vibrator, **17/6**.

COIL PACKS. Manufacturers' surplus. Miniature size, only 2½in. × 3½in. × 1½in. deep. Iron-cored. For L.M. and S.W. with gram. position. Switch has 2-inch spindle. Absolutely brand new, complete with circuit. Price only **27/6**, plus 1/6 P. & P. A snip!

AMERICAN INDICATOR UNIT TYPE BC929A. Brand new incorporating 3in. tube 3EP1, with mu-metal shield, 3-6SN7GT 2-6H6GT, 6X5G, 2X2, 6G6G, 9 potentiometers 24 v., transformer, and a host of small components. The whole unit which measures only 8½ in. × 8½in. × 13½in. is brand new, enclosed in black crackle box, and can be supplied at **45/-**, plus 5/- p. & p.

No. 38 TRANSMITTER/RECEIVER WALKIE-TALKIE. Range approx. 5 miles. Coverage 7-9 Mc/s. The set only complete with valves at **25/-**, in very good condition.

We also have available "38" sets absolutely complete with junction box, aerial, headphones, microphone, spare set of valves, with full operating instructions, absolutely brand new in original sealed packing cases, at **99/6** each complete station, plus 5/- carriage. Export enquiries invited.

POWER PACK. By leading manufacturer. Input 200/250 v. Output 350-0-350 250 mA., 6.3 v., 3 a., 6.3 v. 2 a., 4 v. 7 a., 5 v. 2 a. Fully smoothed. Incorporates valve rectifier GZ32. Chassis measure 13in. × 7in. × 5½in. Wt. 22lb. Few only at **£4/19/6**, plus 5/6 p. and p.

THE R.C. RAMBLER ALL-DRY PORTABLE KIT

Full assembly details with practical and theoretical diagrams can be supplied at **1/6** post free. This is a truly professional 4-valve superhet—all dry—for medium and long waves. A cream plastic top panel, with dial engraved in red and green adds to the very imposing appearance of this model which is housed in an attractive cream and grey leatherette covered attache-case type cabinet: measuring only 9in. × 7in. × 5½in. Weight less batteries 4½lb. with batteries 6½lb. This set really has everything. Built-in frame aerial, high quality, extremely sensitive, and very adequate volume from the 5in. speaker. Valve line-up 3V4, 1R5, 1S5, 1T4. Also the required components, exactly as specified, including cabinet, can be supplied from stock at the special inclusive price of **£7/7/-** plus 2/6 p. and p. (less batteries). Uses Ever-Ready 90 v. H.T. type B126 at 10/-. Also L.T. 1.5 v. A.D. 35 at **1/6**.

RAMBLER MAINS UNIT! At last we are able to offer our special mains units kit for using our popular all-dry "Rambler" on A.C. Mains. Complete kit, which when assembled fits snugly into battery compartment, can be supplied at **47/6**, plus 1/6 packing and postage. Price includes all required components, and full assembly instructions. **N.B.**—This unit is completely self-contained in a metal box measuring 7in. × 2½in. × 1½in. and is ideally suitable for ANY all-dry battery portable requiring 90 v. H.T. and 1.5 v. L.T.

B.S.R. MONARCH. The very latest cream 3-speed mixer Auto-changer. Complete with turn-over crystal pick-up. Complete in original manufacturer's cartons, fully guaranteed. Price only **£7/19/6** Carriage Paid. Buy now! Quantity at this price strictly limited.

JUST ARRIVED! Replacement pick-up cartridge for B.S.R. Monarch, etc., type HGP 57. Complete with sapphire stylii, fitted in few seconds. Limited quantity at **15/6** only! Tax paid, post free!

BC.54. Special Purchase! Latest type 3-speed, incorporating "T" type turnover head. Cream finish. Original manufacturer's cartons. **£9/19/6** only, plus 5/6 p. and p. H.P. terms available.

RECORD PLAYER CABINETS. Specially made to house any type of single record unit. Finished in dove-grey leatherette. Base-board measures 14½in. × 12½in. Clearance above and below board 3in., **45/-** plus 5/- P. & P. We can also supply equally attractive dove-grey cabinet to house any standard auto-changer at **60/6** plus 5/- P. & P. We carry a large selection of cabinets for all purposes. A stamp will bring illustrated cabinet leaflets.

R.F. UNITS. All new condition and complete. Case size 9½in. × 7½in. × 8in. **Type 24**, 20-30 Mc/s. **6/6**. Switched Tuning. **Type 25**, 40-50 Mc/s. **10/6**. Switched Tuning. **Type 26**, 50-65 Mc/s. Variable Tuning, **22/6**. ALL these units Post Free.

EX-W.D. CATHODE RAY TUBES. Guaranteed full picture. VCR97 at **40/-**. VCR517C at **35/-**. Also CV1136. Ideal for oscilloscope 2½in. screen at **35/-**. We also have VCR97 with slight cut-off very suitable for oscilloscope, testing purposes, etc., at **15/-** only. All these tubes are brand new, in original packing, tested before despatch. Please add 2/6 packing and carriage for any of the above tubes.

MU-METAL SCREEN for VCR97. Price **10/-** post free.

MAINS TRANSFORMER BARGAINS. Limited quantities. Manufacturers' surplus. 350-0-350, 80 mA., 6.3 v. 3 a., 5 v. 2 a. Half shrouded, drop-through, **14/6** only, plus 1/6 P. & P. 250 v. Input, 300-0-300 80 mA., 6.3 v., 3 a., 4 v. 2 a. Tropicalised drop-through type, **9/6** only, plus 1/6 P. & P. Input 110/230 v. Auto feed 230 v. 750 mA., 350-0-350 150 mA. Tapped filament winding 6. v. 3 a., 15 v. 3 a., 21.5 v. 6 a., also 5 v. 2 a. Tropicalised drop-through type, **21/-** plus 2/6 P. & P. 270-0-270, 100 mA. 6.3 v. 3 a., 5 v. 2 a. 200/250 v. Input universal mounting **16/6**, plus 1/6 P. & P.

6-VOLT VIBRATOR PACK. Ex-W.D. 6-volt input, output 140 v. 30 mA. Fully smoothed and rectified, incorporating Westite 6 volt 4 pin vibrator type NS95. Unit size only 6½in. × 3in. × 5½in. Price **15/-** plus 1/- P. & P. New condition.

RECEIVER TYPE 88/TR. (The receiver section of TR1196). Supplied complete with full data for conversion to 3-wave superhet receiver. Unit is complete with 6 valves 2-EF39, 2-EF36, FK32 and EBC33, also stadard I.F.T.'s 465 Kc/s. Price **27/6** plus 2/6 P. & P.

TR1196 TRANSMITTER PORTION. We can also supply the transmitter portion of the above receiver incorporating valves, EL32, EF50, CV591. Type 600 relay transformer, coils, switches, etc. Limited quantity at **12/6** only, plus 2/6 P. & P.

HEADPHONES. Low resistance. Brand new Ex.-W.D. type CLR. **7/6** per pair, plus 1/6 p. and p. High resistance, 4000 ohms, brand new lightweight **15/-** per pair, plus 1/6 p. & p.

VALVES

We have perhaps the most up-to-date valve stocks in the trade. A stamp will bring complete list but the following is a selection only of brand new imported valve types, fully guaranteed. Purchase Tax Paid.

EABC80	10/-	DAF96	10/6	PL83	11/6
EAF42	10/-	DF96	10/6	PY80	10/6
EB41	7/6	DK92	10/6	PY81	10/-
EB91	7/6	DK96	10/6	PY82	9/6
EBC41	10/-	DL96	10/6	PY83	10/6
EBF80	11/6	or **30/6** per set		UBC41	10/6
ECC81	9/-	of four.		UCH42	11/6
ECC82	9/-	DM70	9/-	UF41	10/6
ECC83	9/-	EL41	10/6	UL41	10/6
ECC84	15/-	EL84	11/6	UY41	9/-
ECC85	10/-	KM80	9/6	6AQ5	8/6
ECF82	15/-	EY51	12/-	6AT6	6/-
ECH42	11/6	EY86	14/6	6AU6	9/6
ECH81	11/6	EZ40	8/6	6BA6	8/6
ECL80	11/6	EZ80	6/6	6BE6	9/-
EF41	10/6	PCF80	12/6	6BW6	9/6
EF80	10/6	PCF82	12/6	6X4	7/6
EF85	10/6	PCC84	12/6	35W4	7/6
EF86	12/6	PL81	13/6	50B5	10/-
EF89	10/-	PL82	10/6	50C5	10/-

In addition we naturally have all usual surplus types available such as 6V6GT, etc. All in our valve price list!

BRAND NEW C.R. TUBES.—By leading manufacturer, 12in., equivalent to MW 31/74 **£11/19/6**. MW36/24 Tinted. Latest type 14in. rectangular 6.3 v. heater. 13-14 Kv. in original sealed cartons. Limited quantity only at **£12/19/6**. Ditto 17in. type 17ASP4. Price **£19/19/6**. All H.P. available. Plus 15/- packing, carriage and insurance.

TRANSISTORS MULLARD TYPE OC.71. Available ex stock at new list price of **24/-** each, post free.

Another Cabinet Bargain. Special purchase of walnut veneered trolley-type cabinets originally intended for use in projection T.V. Easily recognised as being of leading High Quality manufacturer's stock, heavy dark solid walnut. Can be easily adapted to house tape recorder, amplifier, radiogram, etc., etc. Measurements external 24½in. × 16in. × 29in. The whole is mounted on castors. Unrepeatable bargain at **£5/19/6**, plus 10/- packing and carriage. We have a large selection of all type cabinets. A stamp will bring list.

CLYNE RADIO LTD.

18, Tottenham Court Road, London, W.1.

R.S.C. BATTERY CHARGING EQUIPMENT

All for A.C. MAINS 200-250v., 50 c/cs. Guaranteed 12 months.

ASSEMBLED CHARGER
6 v. or 12 v. 2 amps.
Fitted Ammeter and selector plug for 6 v. or 12 v. Louvred metal case, finished attractive hammer blue. Ready for use with mains and output leads. Double Fused.
Only **46/9** carr. 3/6.

ASSEMBLED CHARGERS
6 v. 1 amp 19/9
6 v. or 12 v. 1 amp. .. 25/9
6 v. 2 amps. 29/9
6 v. or 12 v. 2 amps. .. 38/9
6 v. or 12 v. 4 amps. .. 56/9
Above ready for use. Carr. 2/9

HEAVY DUTY KIT
12 v. 30 amp. Suitable for garage or firm with a number of vehicles. Mains input 200/250 v. 50 c/s. Outputs 12 v. 15 amp. twice. Consists of Mains Trans. 2 Metal Rectifiers. 2 Meters. 4 Fuses. 4 Terminals. 2 Rheostats and circuit. Only 9 gns., carr. 15/-.

BATTERY CHARGER KITS
Consisting of Mains Transformer, F.W. Bridge, Metal Rectifier, well ventilated steel case, Fuses, Fuse-holders, Grommets, panels and circuit. Carr. 2/6 extra.
6 v. or 12 v. 1 amp. .. 22/9
6 v. 2 amps. 25/9
6 v. or 12 v. 2 amps. .. 31/6
6 v. or 12 v. 4 amps. .. 49/9

BATTERY CHARGER KIT
Consisting of F.W. Bridge Rectifier 6/12 v. 5 a. Mains Trains., 0–9–15 v. 6 a. output, and variable charge rheostat with knob. Only 45/9. Post 3/-.

Assembled 6 v. or 12 v. 4 amps.
Fitted Ammeter and variable charge selector. Also selector plug for 6 v. or 12 v. charging. Double fused. Well ventilated steel case with blue hammer finish. **69/6**
Ready for use with mains and output leads. Carr. 3/6.

SELENIUM RECTIFIERS

L.T. Types		6/12 v. 6 a. ..	19/9
2/6 v. ½ a.h.w.	1/9	6/12 v. 10 a. ..	25/9
6/12 v. ½ a.h.w.	2/9	**H.T. Type H.W.**	
F.W. Bridge Types		120 v. 40 mA.	3/9
6/12 v. 1 a. ..	5/9	250 v. 50 mA.	5/9
6/12 v. 2 a. ..	8/9	250 v. 80 mA.	7/9
6/12 v. 3 a. ..	12/9	250 v. 150 mA.	9/9
6/12 v. 4 a. ..	16/9	300 v. 275 mA.	12/11

CO-AXIAL CABLE. 75 ohms, ½in., 8d. yard. Twin screened feeder, 11d. yard.

5 CORE FLEX. Henleys circular rubber 14/36. Each lead colour coded. 1/6 yd.

T.V. CABINETS. For 15, 16 or 17in. tube. Table model with doors, 79/6, carr. 7/6. Table type for 12in. tube, 27/6, carr. 5/6. All leading manufacturers surplus.

SILVER MICA CONDENSERS. 5, 10, 15, 20, 25, 30, 35, 50, 100, 120, 150, 180, 200, 230, 300, 330, 400, 470, 500, 1,000 pfd. (.001μF), .002 mfd. (2,000 pfd.). All at 6d. each, 3/9 dozen one type.

DIAL BULBS, M.E.S., 8 v. 0.2 a., 6/9 doz. 6.5 v. 0.3 a., 6/9 doz.

ELECTROLYTICS (current production). NOT Ex Govt.

Tubular Types		Can Types	
8μF 450v. ..	1/9	8 mfd. 350 v.	1/3
8 mfd. 500 v.	2/6	8 mfd. 600 v.	2/11
16μF 350 v. ..	2/3	16 mfd. 350 v.	1/11
16μF 450 v. ..	2/9	16μF 450 v. ..	2/9
16μF 450 v. ..	2/9	16 mfd. 500 v.	3/9
16μF 500 v. ..	3/9	32μF 350 v. ..	2/11
32μF 350 v. ..	3/9	32 mfd. 450 v.	4/9
32 mfd. 500 v.	5/9	100 mfd. 450 v.	4/9
8-16μF 500 v.	4/11	8-8μF 450 v. ..	2/9
25μF 25 v.	1/3	8-16μF 450 v.	2/11
50μF 12 v.	1/3	16-16μF 450 v.	3/11
50 mfd. 25 v.	1/9	16-32μF 350 v.	4/9
50μF 50 v.	1/9	32-32μF 350 v.	4/9
100 mfd. 12 v.	1/9	32-32μF 450 v.	5/9
100 mfd. 25 v.	2/3	64-120 mfd. 350v.	7/6
		100-200 mfd. 275 v.	6/11

Many others in stock.

VOLUME CONTROLS with long spindles, all values, less switch, 2/9; with S.P. switch, 3/9.

VIBRATORS. Oak 2 v. 7 pin, synchronous, 7/9.

EX GOVT. E.H.T. CONDENSERS
.5 mfd., 2,500 v. Blocks 3/9
.1 mfd. plus 1 mfd. 8,000 v., large blocks (common negative isolated) 9/6

EX GOVT. METAL BLOCK PAPER CONDENSERS

2 mfd. 500 v. ..	1/9	10 mfd. 600 v.	6/9
4 mfd. 500 v. ..	2/8	8-8 mfd. 500 v.	5/11
8 mfd. 500 v. ..	5/9	15 mfd. 500 v.	7/9
4 mfd. 400 v. plus 2 mfd. 250 v.			1/11

EX GOVT. VALVES. VR137, EA50, EB34, 11d.; SP61 2/3; 4SHA 1/3; EL32 3/9; 6X5 4/9.

EX GOVT. UNITS, type RDF1 in original sealed cartons with 14 valves including 5Z4G, etc., trans., L.F. choke, Rectifier, etc., etc. We cannot enter into correspondence regarding these units which represent a really exceptional bargain at 29/9. Carr. 7/6.

CONTROL PANEL with 1 six-position 3-wafer Yaxley switch, 1 pointer knob. 2 S.P.S.T. switches, various plugs and sockets. Only 1/6.

OIL FILLED BLOCK CONDENSERS
Bryce 11-7 mfd. 500 v. New unused Govt. surplus, only 5/9 each.

EX GOVT. MAINS TRANSFORMERS
All 230 v. 50 c/s. input
8.8 v. 4 a., 9/9. 120-0-120 v. 40 mA. .. 5/9
300-0-300 v. 150 mA. 4 v. 3 a. 9/9
250-0-250 v. 60 mA. 6.3 v. 2 a., 5 v. 2 a. Potted 4½-3½-3in. 11/9
460 v. 200 mA., 6.3 v. 5 a. 22/9
0-16-18-20 v. 35 a., 79/6. Carriage 5/- extra.

MANUFACTURERS SURPLUS TRANSFORMERS
Fully shrouded upright. Primary 200-230-250 v. Sec. 425-0-425 v. 150 mA. 6.3 v. 3 a., 5 v. 3 a., 33/9. Clamped type 325-0-325 v. 100 mA. 6.3 v. 3.5 a., 5 v. 2 a. Wearite 19/9. Post 2/9.

EX GOVT. SMOOTHING CHOKES

250 mA., 10 H., 50 ohms	14/9
250 mA., 3 H., 50 ohms	8/9
150 mA., 10 H., 150 ohms	10/11
150 mA., 6-10 H., 150 ohms, Tropicalised	6/9
100 mA., 10 H., 100 ohms, Parmeko	6/9
100 mA., 10 H., 200 ohms, Tropicalised	3/11
50 mA., 50 H., 1,000 ohms	6/9
L.T. type 1 amp., 2 ohms	2/9

SPECIAL OFFERS. Small 2 gang variables .005 mfd., 4/9. 8-8 mfd., 450 v. Electrolytics (midget) in lots of six, 1/6 ea.

R.S.C. BATTERY TO MAINS CONVERSION UNITS

Type BM1 An all dry battery eliminator. Size 5½ × 4½ × 2in. approx. Completely replaces batteries supplying 1.4 v. and 90 v. where A.C. mains 200-250 v. 50 c/s. is available. **Suitable for all battery portable receivers requiring 1.4 v. and 90 v.** This includes latest low consumption types. Complete kit with diagrams 39/9, or ready for use, 46/9.

Type BM2. Size 8 × 5½ × 2½in. Supplies 120 v., 90 v. and 60 v., 40 mA. and 2 v. 0.4 a. to 1 amp. fully smoothed. **THEREBY COMPLETELY REPLACING BOTH H.T. BATTERIES AND L.T. 2v. ACCUMULATORS.** When connected to A.C. mains supply 200-250 v. 50 c/s. SUITABLE FOR ALL BATTERY RECEIVERS normally using 2 v. accumulator. Complete kit with diagrams and instructions 49/9 or ready for use 59/6.

PLESSEY DUAL CONCENTRIC 12in. P.M. SPEAKERS. (15 ohms), consisting of a high quality 12in. speaker, of orthodox design supporting a small elliptical speaker ready wired with choke and condensers to act as tweeter. This high fidelity unit is highly recommended for use with our A8 or any similar amplifier. Rating is 10 watts. Price only £5/17/6.

MAINS ENERGISED SPEAKERS R.A. 2-3 ohms. 8in. Field 600 ohms., 10/9. 10in. Field 1,500 ohms., 23/9.

R.S.C. TRANSFORMERS

FULLY GUARANTEED, INTERLEAVED AND IMPREGNATED

MAINS TRANSFORMERS
Primaries 200-230-250 v. 50 c/s.

FULLY SHROUDED UPRIGHT MOUNTING
250-0-250 v. 60 mA. 6.3 v. 2 a., 5 v. 2 a., Midget type, 2½-3-3in. 17/6
350-0-350 v. 70 mA., 6.3 v. 2 a., 5 v. 2 a. 250-0-250 v. 100 mA., 6.3 v.-4 v. 4 a., c.t., 0-4-5 v. 3 a. 19/9
250-0-250 v. 100 mA., 6.3 v. 4 a., 5 v. 3 a. 23/9
250-0-250 v. 100 mA., 6.3 v. 6 a., 5 v. 3 a., for R1355 conversion 31/-
300-0-300 v. 100 mA., 6.3 v. 4 a., 5 v. 3 a. 300-0-300 v. 100 mA., 6.3 v. 4 v. 4 a., c.t., 0-4-5 v 3 a. 23/9
350-0-350 v. 100 mA., 6.3 v. 4 a., 5 v. 3 a. 300-0-300 v. 130 mA., 6.3 v. 4 a., c.t., 6.3 v. 1 a., suitable for Mullard 510 Amplifier 26/9
350-0-350 v. 100 mA., 6.3 v.-4 v., 4 a., c.t., 0-4-5 v. 3 a. 26/9
350-0-350 v. 150 mA., 6.3 v. 4 a., 5 v. 3 a. 350-0-350 v. 150 mA., 6.3 v. 2 a., 6.3 v. 2 a., 5 v. 3 a. 33/9
425-0-425 v. 200 mA., 6.3 v. 4 a., c.t., 6.3 v. 4 a. c.t., 5 v. 3 a., suitable Williamson Amplifier, etc. 49/9
450-0-450 v. 250 mA., 6.3 v. 6 a., 6.3 v. 6 a., 5 v. 3 a. 69/6

TOP SHROUDED DROP-THROUGH TYPE
250-0-250 v. 70 mA. 6.3 v. 2.5 a. 13/9
260-0-260 v. 70 mA., 6.3 v. 2 a., 5 v. 2 a. 16/9
350-0-350 v. 80 mA., 6.3 v. 2 a., 5 v. 2 a. 18/9
250-0-250 v. 100 mA., 6.3 v. 4 a., 5 v. 3 a. 22/9
300-0-300 v. 100 mA., 6.3 v.-4 v. 4 a., c.t., 0-4-5 v. 3 a. 23/9
350-0-350 v. 100 mA., 6.3 v. 4 a. c.t., 5 v. 3 a. 22/9
350-0-350 v. 100 mA., 6.3 v.-4 v. 4 a. c.t., 0-4-5 v. 3 a. 23/9
350-0-350 v. 150 mA., 6.3 v. 4 a., 5 v. 3 a. 29/9

E.H.T. TRANSFORMERS, 2,500 v. 5 mA., 2-0-2 v. 1.1 a., 2-0-2 v. 1.1 a., for VCR97, VCR517 ..... 36/6

FILAMENT TRANSFORMERS
Primaries 200-250 v. 50 c/s.

6.3 v. 1.5 a...	5/9	0-2-4-5-6.3 v.	
6.3 v. 2 a.	7/6	4 a.	16/9
0-4-6.3 v. 2 a....	7/9	6.3 v. 6 a. ..	17/6
6.3 v. 3 a.	8/11	12 v. 3 a. or	
12 v. 1 a.	7/9	24 v. 1.5 a..	17/6

CHARGER TRANSFORMERS
All with 200-230-250 v. 50 c/s. Primaries:
0-9-15 v. 1½ a., 11/9; 0-9-15 v. 3 a., 16/9; 0-3.5-9-17 v. 3 a., 17/9; 0-3.5-9-17 v. 4 a., 18/9; 0-9-15 v. 5 a., 19/9; 0-9-15 v. 6 a., 23/9; 0-9-15 v. 7.5 a., 28/9.

ELIMINATOR TRANSFORMERS
Primaries 200-250 v. 50 c/s.
120 v. 40 mA., 5-0-5 v. 1 a. 14/9
90 v. 15 mA., 6-0-6 v., 250 mA. 9/11

OUTPUT TRANSFORMERS
Midget Battery Pentode 66:1 for 3S4, etc. 3/6
Small Pentode, 5,000Ω to 3Ω 3/9
Standard Pentode, 5,000Ω to 3Ω 4/9
Standard Pentode, 8,000Ω to 3Ω 4/9
Multi-ratio 40 mA. 30:1. 45:1, 60:1. 90:1, Class B Push-Pull 5/6
Push-Pull 8 Watts 6V6 to 3 ohms..... 8/9
Push-Pull 10-12 Watts 6V6 to 3Ω or 15Ω 15/9
Push-Pull 10-12 Watts to match 6V6 to 3-5-8 or 15Ω 16/9
Push-Pull 15-18 Watts, sectionally wound, 6L6, KT66, etc., to 3 or 15 ohms..... 21/9
Push-Pull 10-15 Watts, Ultra Linear, designed for Mullard Amplifier 510.. 39/6
Push-Pull 20 Watt high-quality sectionally wound, 6L6, KT66, etc., to 3 or 15Ω 47/9
Williamson type exact to spec..... 85/-

SMOOTHING CHOKES

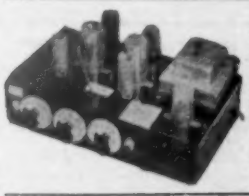
250 mA., 5 H., 100 ohms.	11/9
150 mA., 7-10 H., 250 ohms.	11/9
100 mA., 10 H., 200 ohms.	8 9
80 mA., 10 H., 350 ohms.	5/6
60 mA., 10 H., 400 ohms.	4/11

R.S.C. A6 ULTRA LINEAR 30 WATT AMPLIFIER

NEW 1956 DESIGN. HIGH FIDELITY PUSH-PULL UNIT EMPLOYING SIX VALVES. Tone Control Pre-amp stages are incorporated. Sensitivity is extremely high Only 30 millivolts minimum input is required for full output. **THIS ENSURES THE SUITABILITY OF ANY TYPE OR MAKE OF MICROPHONE OR PICK-UP.** Separate Bass and Treble controls give both "lift" and "cut" with ample tone correction for long playing records. **AN OUTPUT SOCKET WITH PLUG IS INCLUDED FOR SUPPLY OF 300 v. 20 mA. and 6.3 v. 1.5 a. FOR A RADIO FEEDER UNIT.** Price in kit form with easy-to-follow wiring diagrams. **9 GNS.** Only Carr. 10/-. Or Factory built with 12 months' guarantee. 50/- extra. **TERMS ON ASSEMBLED UNITS: DEPOSIT 28/9 and 9 monthly payments of 28/9.** If required an extra input with associated vol. control can be provided so that two separate inputs such as "mike" and gram., etc., etc., can be simultaneously applied for mixing purposes. Extra cost of this 13/-. Cover as illustrated 17/6 extra.

Type 807 output valves are used with High Quality Sectionally wound output transformer specially designed for Ultra Linear operation. Negative feedback of 17 D.B. in main loop. **CERTIFIED PERFORMANCE FIGURES ARE EQUAL TO MOST EXPENSIVE UNITS AVAILABLE.** Frequency response ± 3 D.B., 30-20,000 c/cs., 12 D.B. "lift" at 50 c/cs., 12 D.B. "lift" at 12,000 c/cs., Hum and noise 70 D.B. down. Good quality reliable components used. Chassis finish blue crackle. Overall size 12 × 9 × 9in. approx. Power consumption 150 watts. For A.C. mains 200-230-250 v. 50 c/cs. Outputs for 3 and 15 ohm speakers. **EQUALLY SUITABLE FOR THE CONNOISSEUR OR FOR LARGE HALLS, CLUBS, or OUTSIDE FUNCTIONS. IDEAL FOR USE WITH MUSICAL INSTRUMENTS SUCH AS STRING BASS, ELECTRONIC ORGAN, GUITAR, etc. FOR DANCE BANDS, GARRISON THEATRES, etc., etc.** We can supply Microphones, Speakers, Rotary Converters, etc., at keen cash prices or on H.P. terms with amplifiers.

EXPORT ENQUIRIES INVITED



R.S.C. TA1 HIGH QUALITY TAPE DECK AMPLIFIER

FOR ALL DECKS WITH HIGH IMPEDANCE RECORD/PLAYBACK AND ERASE HEADS. Such as Lane, Truvox, etc. Chassis size 12-7-3in. Overall size 12-7-4½in. For 230-250 v. 50 c/cs. A.C. mains. Output for standard 2-3 ohm speaker. Only 15 millivolts input required for full recording. Only 2 millivolts minimum input required from recording head. Magic Eye recording level indicator. Provision for feeding P.A. amplifier. Can be used as gram. amplifier with input of 0.75 v. R.M.S. Negative feedback equalisation. Linear frequency response ± 3 D.B. 50-11,000 c/cs.

11 GNS. Carr. 7/6

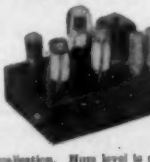
Facilities for recordings at 15in., 7½in. or 3¾in. per second. Automatic equalisation at the turn of a knob. When switching from record to playback position automatic demagnetisation of heads is assured. **PERFORMANCE IS COMPARABLE WITH UNITS AT OVER TWICE THE COST. LEAFLET 6d.**

GARRARD 3-SPEED AUTOMATIC RECORD CHANGERS. Latest Model, Type RC110. Fitted high fidelity turnover crystal pick-up head. For 200-250 v. A.C. mains. Limited number. Brand new cartoned. Only **£8/17/6**, plus 5/6 carriage.

H.M.V. LONG PLAYING RECORD TURNTABLE COMPLETE WITH CRYSTAL PICK-UP (SAPPHIRE STYLUS). Speed 33⅓ r.p.m. **BRAND NEW, CARTONED.** Only **£3/19/6** (approx. half price). Carr. 5/- (for 200-250 v. A.C. Mains).

MICROPHONES. High fidelity crystal types. Acos 33-1 hand or desk type, 50/-. Piezo with heavy floor base and telescopic stem, **£6/19/6.**

R.S.C. 4-5 WATT HIGH GAIN AMPLIFIER TYPE A5



A highly sensitive 4-valve quality amplifier for the home, small club, etc. Only 50 millivolts input is required for full output so that it is suitable for use with the latest high-fidelity pick-up heads in addition to all other types of pick-ups and practically all mikes. Separate Bass and Treble controls are provided. These give full long playing record equalisation. Hum level is negligible, being 71 D.B. down, 15 D.B. of negative feedback is used. H.T. of 300 v. 20 mA. and L.T. of 6.3 v. 1.5 a. is available for the supply of a Radio Feeder Unit or Tape Deck pre-amplifier. For A.C. mains input of 200-230-250 v., 50 c/s. Output for 2-3 ohm speaker. Chassis is not alive. Kit is complete in every detail and includes fully punched chassis (with baseplate) with the blue hammer finish, and point-point wiring diagrams and instructions. Exceptional value at only **£4/15/-**, or assembled ready for use **25/-** extra, plus 5/6 carriage.

R.S.C. A73-4 WATT QUALITY AMPLIFIER

A highly sensitive 4-valve amplifier using negative feedback and having an excellent frequency response. Pre-amplifier and Tone Control stages are incorporated with separate Bass and Treble controls giving full tone compensation for Long Playing records. Suitable for any kind of pick-up including latest high fidelity types. H.T. of 250 v. 20 mA. and L.T. 6.3 v. 1 a. available for supply of Radio Feeder Unit, etc. ONLY 40 millivolts input required for full output. Fully tested chassis with baseplate. For A.C. mains 200-250 v. 50 cycles. Output for 2-3 ohm speaker. Complete kit of parts with point-to-point wiring diagrams and instructions. Only **£3/15/-**, carr. 5/6 or factory built **22/6** extra.

BRAND NEW B.S.R. MONARCH 3-SPEED MIXER AUTO-CHANGERS. With crystal pick-up and dual point sapphire stylii for standard or long playing records. Plays ten 7in., 10in. or 12in. intermixed. For A.C. mains 200-250 v. 50 c/cs. Supplied in sealed cartons with complete and operating instructions, **£7/15/-** plus 5/6 carr.

WALNUT VENEERED CABINETS. Designed for above record changers with provision for housing amplifier and speaker. Attractive design. Limited number. Brand new cartoned **£3/10/6**, carr. 7/6.

QUALITY AMPLIFIERS. 2-4 watt, specially designed for use with B&R changer and above cabinet. Latest miniature type valves used. Separate Bass and Treble Controls and Vol. Control with mains switch. For A.C. 200-250 v. mains. Ready for use, only **£3/10/6**, carr. 3/6.

P.M. SPEAKERS. Suitable for use with above equipment. Elliptical 7 × 4in. with 2-3 ohms speech coil, **10/9** ea.

COLLARO HIGH FIDELITY MAGNETIC PICK-UPS. High impedance, brand new, boxed at fraction of normal price. Only **31/-.**

P.M. SPEAKERS. 2-3 ohm., 8in. Goodmans, **17/9**, 6½in. R.A., **15/9**, 8in. Rola, **19/9**, 10in. R.A., **26/9**, 12in. Fisher, **29/11.**

THE SKY FOUR T.R.F. RECEIVER

A design of a 5-valve 200-250 v. A.C. Mains receiver with selenium rectifier. For inclusion in either of cabinets illustrated above. It employs valves 6K7, EF91, 6P36, and is specially designed for simplicity in wiring. Sensitivity and quality is well up to standard. Point-to-Point wiring diagrams, instructions and parts list, 1/9. This receiver can be built for a maximum of **£4/19/6** including cabinet. Available in brown or cream bakelite, veneered walnut.

R.S.C. ULTRA LINEAR 12-WATT AMPLIFIER

NEW 1956 MODEL A8 HIGH-FIDELITY PUSH-PULL AMPLIFIER WITH "BUILT-IN" TONE CONTROL, PRE-AMP. STAGES.

High sensitivity. Includes 5 valves (807 outputs). High Quality sectionally wound output transformer, specially designed for Ultra Linear operation, and reliable small condensers of current manufacture. INDIVIDUAL CONTROLS FOR BASS AND TREBLE "Lift" and "Cut." Frequency response ± 3 db. 20-20,000 c/cs. Six negative feedback loops. Hum level 71 db. down. ONLY 70 millivolts INPUT required for FULL OUTPUT. Suitable for use with all makes and types of pick-ups and pre-tically all microphones. Comparable with the very best designs. **For STANDARD or LONG PLAYING RECORDS. For MUSICAL INSTRUMENTS such as STRING BASS, GUITARS, etc. OUTPUT SOCKET** with plug provides 300 v. 20 mA. and 6.3 v. 1.5 a. For supply of a **RADIO FEEDER UNIT. H.P. TERMS ON ASSEMBLED UNITS. DEPOSIT 25/6** and nine monthly payments of **22/4.** Size approx. 12-9-7in. For A.C. mains 200-230-250 v. 50 c/cs. Output for 3 and 15 ohm speakers. Kit is complete to last nut. Chassis is fully punched. Full instructions and point-to-point wiring diagrams supplied.

Unapproachable value at **£7/15/-** *or factory built* **45/-** extra. Carriage 10/-. If required louvred metal cover with 2 carrying handles can be supplied for **17/6.** Where an extra input socket with associated volume control is required for mixing purposes this can be provided for **12/-** extra.

ROTARY CONVERTERS. 200 watts. Input 12 v. D.C. Output 230 v. 50 c/cs. A.C. Only **7 gns.** Carr. 7/6.

FOUR-STAGE RADIO FEEDER UNIT

Design of a HIGH FIDELITY L. and M. wave T.R.F. Unit with self-contained heater supply and thorough H.T. decoupling. Only 250-300 v. 15-20 mA. H.T. required from main amplifier. Three valves and Low Distortion Germanium Diode Detector. Flat topped response characteristic. Loaded H.F. coils. Two variable Mu-controlled H.F. stages, 3 gang condenser tuning. Cathode follower output stage. Switch position for Gram. and Gram. input and output sockets. Performance comparable with the best in Feeder Units. For A.C. mains 200-230-250 v. operation. Size 11-6-7½in. Illustrations full set or easy-to-follow wiring diagrams and instructions and individually priced parts list **2/6.** This unit can be built for only **£3/15/-**, including Dial and Drive knobs and every item required.

DEFIANT RECORD PLAYING TURNTABLE COMPLETE WITH MAGNETIC PICK-UP. Pick-up is high impedance type. Unit is housed in a beautiful walnut veneered cabinet of attractive design. For all standard records (78 r.p.m.) Limited number. Brand new, cartoned, **£5/17/6**, carr. 7/6.

W.B. "STENTORIAN" HIGH FIDELITY P.M. SPEAKERS. HF1012, 10 watts, 15 ohm (or 3 ohm) speech coil. Where a really good quality speaker at a low price is required, we highly recommend this unit with an amazing performance **£4/10/9.** *Please state whether 3 ohm, or 15 ohm. required.*

Radio Supply Co. (LEEDS) LTD.

32 THE CALLS. — LEEDS, 2.

Terms C.W.O. or C.O.D. No C.O.D. under £1. Postage 1/9 extra on *all* orders under £2, 2/9 extra under £5 unless carriage charge stated. Full Price List 6d. Trade List 5d. Open to Callers: 9 a.m. to 5.30 p.m. Saturday until 1 p.m.

LASKY'S RADIO

SAVE POUNDS! ORDER BY POST IF YOU CANNOT CALL

HIRE PURCHASE TERMS available on certain items. Write stating requirements.

SEND FOR OUR NEW LIST enclosing 3d. in stamps.

MOVING COIL P.M. SPEAKERS

3in. and 3½in. 19/6

5in.	6½in.	8in.	10in.	12in.
16/6	17/6	25/-	26/6	29/6

6½in. with trans. 21/-
7 × 4in. Elliptical .. 19/6
10 × 6in. Elliptical .. 32/6

DECCA XMS P.U. HEADS

L.P. and standard, complete with styli. Per pair, **79/6** Post 3/6. Single, 42/-. Post extra.

T.O. CRYSTAL CARTRIDGES

B.S.R. complete with two styli. Post free **18/6**

SPECIAL OFFER! 14" TABLE MODEL TV CABINETS

Complete with mask and filter glass 6½in. closed field P.M. Speaker incorporated. Overall dim.: 18½in. wide, 15½in. high, 16in. deep. Dark veneer finish with light top. LASKY'S PRICE **45/-**

Carr. and packing, 9/6.

LARGE SELECTION OF CABINETS for radiograms, carrying cases for record players, tape recorders, TV, etc. Your enquiries invited.

VALRADIO TV TUNERS

Full range, all I.F. freq., series or parallel heaters, £6. Post 3/6.

THE NEW JASON "ARGONAUT" AM/FM TUNER

A super-sensitive Tuner for F.M. and medium waves. The complete parcel with power supplies, **£13.19.6** Post 3/6.

Data Book 2/-, post free.

All components available separately. Send for itemised price list.

Chassis Assembly, complete, 57/9. Post 2/6.

I.F. and Coil Set, complete 78/-. Post 1/6.

JASON F.M. TUNER

Special parcel containing data book, chassis, front end, dial, drive, tuning condenser, full set of coils, I.F.s, ratio detector, etc. Post 2/6. **68/9**

Book only, with price list, 2/-. This Tuner uses 4-6AM6 and 2 crystals and can be built for £6/15/-, plus 3/6 post.

MAKE YOUR OWN FERRITE ROD AERIAL. Ferrite rod, 5in. long, ¼in. diam., with full directions. Each, 2/6. Post 1/-.

SINGLE RECORD PLAYERS

Collaro 3/554 ..... £8 18 4
B.S.R. Model TU.8 £4 12 6
Garrard "TB" Units, less heads £8 10 11
Carr. 3/6.

PROJECTION TV UNITS

(Mullard.) Consisting of optical unit and E.H.T. unit, complete with valves and C.R. tube. Limited quantity. Full details on request. LASKY'S PRICE **£21**
Carr. 21/-.

LASKY'S RECORD VALUE IN 3-SPD. MIXER AUTO-CHANGERS

ALL BRAND NEW AND UNUSED, IN MAKERS' CARTONS

GARRARD RC.110, as illus. Complete with t.o. crystal pick-up. Cabinet space required 14 × 12½ × 4in. above, and 2½in. below motor board. Cream and brown enamel finish. Complete with instruction book. List £14/13/-. LASKY'S PRICE **£8.19.6**

Carr. 5/-. Cabinets available, list on request.

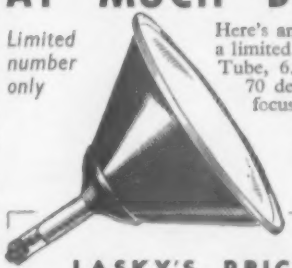
GARRARD RC.80. Full length arm with two Decca XMS heads. List £20/15/-. LASKY'S PRICE **£13.19.6** Carr. 5/-.
As above, with GC.2 t.o. crystal head, £15.15.0.

BSR Monarch. With H.G.P.37 t.o. crystal P.U. **£7.19.6** Carr. 3/6.

COLLARO RC.54. With studio O t.o. crystal P.U. **£9.19.6** Carr. 5/-.

16 INCH METAL CONE C.R. TUBES AT MUCH BELOW HALF PRICE!

Limited number only



Here's an offer you simply cannot afford to miss, but hurry, a limited number only are available. 16in. Metal Cone C.R. Tube, 6.3 v. heater, ion trap, 14 Kv. E.H.T., wide angle 70 deg., standard 38 mm. neck, duodecal base, magnetic focus and deflection. Max. length 17 11/16in.

Gives large black and white picture size 11 × 14¼in. Supplied unused in original cartons.

LASKY'S PRICE
£9.19.6
Carr. and Insurance 22/6 extra.

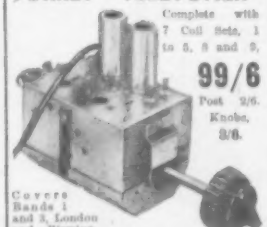
Guaranteed by us for 3 months. Full data, connections and suggested time bases supplied with every tube.

LISTED AT £23.9.10

Masks, Anti-Corona Rings, Bases and Ion Traps available.

Big Picture Television at a price you can afford!

FAMOUS MAKE TURRET "TELETUNER"



Complete with 7 Coil Sets, 1 to 5, 8 and 9, **99/6** Post 2/6. Knobs, 3/6.

Covers Bands 1 and 3, London and Birmingham. Valves used: PCC84, R.F. double triode, cascode R.F. amplifier, PCF80, triode pentode f.c. and mixer. I.F. output 33-38 Mc/s. Easily modified to other I.F. outputs. Full instructions and circuit diagram supplied.

DULCI F.M. TUNER

Incorporates its own power supply and operates with most radio receivers and any make of Amplifier. Valve line up: EABC80, ECC85, two EF89, 6X4 (Rect.), EM80, magic eye Indicator. Incorporates GORLER Inductance Tuning Heart. Dial 10½ × 6in. Overall size 9 × 6 × 5½in. high. Complete **16 GNS.**
Carr. & Pkg. 7/6.
DULCI A.M./F.M. TUNER £23.12.0.

12-CHANNEL TV TUNERS

Famous make. Covers Bands I and III. Complete with valves EF80 and ECC81. Ceramic valve holders, finest quality components. Switch and fine tuning. I.F. output 20-25 Mc/s. Freq. coverage 50-67 Mc/s. and 175-215 Mc/s. Full details and circuit diagram supplied. Reduced to **79/6** Post 3/6. KNOBS 2/9 extra.

Also another Tuner using PCC84 and PCF80, I.F. output 33-38 Mc/s. Complete with valves and diagram. **99/6**. Post 3/6.

TELETRON BAND III CONVERTERS

MK. I. Complete Kit to build this converter, drilled chassis, condensers, resistances, coils, 2-E880 valves, etc., with circuit diagram and instructions. Post 1/6. **48/6**

Drilled chassis only, 3/9.

MK. II. Uses latest type valves. Cascode R.F. amp. and triode pentode F.C. PCC84 and PCF80, etc. The COIL SET. **17/6**

COMPLETE KIT, including drilled chassis, valves and diagram, Post 1/6. **59/6**

Circuit diagram only, 3d.

TELETRON CONVERTER COIL SET. For use with TRF and S'het Band I TV sets. Uses two Z719. Circuit diagram alignments, full details supplied. Post 1/6. **15/-**

MICROPHONE SNIP

Table Crystal, with screened lead. Post 2/6 **21/-**

Large selection all types, high and low impedance, moving coil, crystal, ribbon, etc.

GERMANIUM CRYSTAL DIODES

GEX.00	1/6
GEX.34	3/6
GEX.54	5/-
OA.71	5/-
WG4A	3/6
WG4B	4/-
WG5A and B	5/-
WG6A	5/-

REMPLOY INSTRUMENT SOLDERING IRONS. 200-250 v. Neon indicator light. in handle **19/3**

BAND III CONVERTERS

2 valves and metal rectifiers, metal case. Contains power pack for 200-250 v. A.C. List £8/10/-. LASKY'S PRICE **79/6**

DECCA PICK-UPS

3-speed with T.O. crystal head HI/G, and rest. Brown plastic. Post 2/6. **42/6**

RADIO · TELEVISION · HI-FI · ELECTRONICS · RECORDERS

LASKY'S RADIO

Special Bargain

3-WATT AC/DC MIDGET AMPLIFIER

Push pull, very high gain. 4 valves: two UL41 (p.p.) UCH42, UAF42. Input voltage 100/110 A.C./D.C. Easily converted to 230 v. Ideal for record players, tape recorders, baby alarms, etc. Supplied fully assembled with valves, circuit diagram and details. **REDUCED TO 50/-** Carr. 5/-.

LASKY'S RADIO CONSTRUCTOR PARCELS

No. 1. Contains everything to build a 4-valve, 3-wave superhet for 200-250 A.C. mains. Wood or plastic cabinet as preferred. Can be built for **£7.19.6** Carr. 2/6.

No. 2. Contains everything to build a T.F.R. 3-valve, 3-wave set for 200-250 A.C. mains. Wood or plastic cabinet as preferred. Can be built for **£5.10** Carr. 2/6.

INSTRUCTION BOOKS for above, 1/- each, post free. All components available separately.

LARGE RANGE OF TAPE DECKS

Collaro "Tape Transcripter", £20
Truvox, 22 Gns.
Lane, £18/10/-.
Brenell, 18 Gns.
And all other makes.

TAPE DECK MOTORS

Anti-clockwise, shaded pole. Special offer, COLLARO, 25/-. GARRARD, 26/6. B.T.H., 29/6. Post extra.

FAMOUS AMPLIFIERS BUILT ON T.C.C. PRINTED CIRCUITS

All specified components used, with your choice of transformers and chokes. Fully assembled and ready for use.

The **MULLARD 510.** Price, according to transformers used, from **14 gns.** The Book, **3/6.**

OSRAM 912. From **18 GNS.** The Book, 4/-, post free.

All components available separately, also printed Circuits.

R1155 RECEIVERS

In original wood transit cases.

Brand New	£11	19	6
Second-hand, Grade 1	£9	19	6
Ditto, Grade 2	£7	19	6

Carr. 12/6.

Power Pack and Output Stage with 6½in. Speaker.. £5 5 0

FILAMENT TRANSFORMERS

6.3 v. 1.5 amp.	5 11
6.3 v. 3 amp.	7 6
6.3. v 1 amp.	4 6
0–30 volts	19 6

METER BARGAINS

2½in. moving coil. Brand new micro-ammeters F.S.D. 0-750 micro/amps., 15 ohms resist. 15/-.
0-1.5 amps., 12/6. 0-200 v. A.C., rect. incorporated, 12/6.
Dozens of other types.

TRANSISTORS

Lowest prices. Fully guaranteed. By Mullard, S.T.C., etc.
SUB-MINIATURE TRANSISTOR TRANSFORMERS, 4 to 1 ratio. Each 4/6.

SPECIAL OFFER OF PORTABLE GRAM AMPLIFIERS

Uses 3 latest miniature valves, U78, N78, DH77. Volume, bass and treble controls; extension L.S. socket and internal L.S. switch, indicator lamp. Mounted on wood baffle, overall size 14 × 4½in. with speaker centralised. All top quality new components. For A.C. mains 200-250 v. Ideal for portable record players, input will match Monarch. RC54, RC3/554, etc.

Price, complete with 3 new Osram valves, 7 × 4in. Goodmans elliptical speaker, metal speaker grille mains lead, and knobs. **£5.9.6**

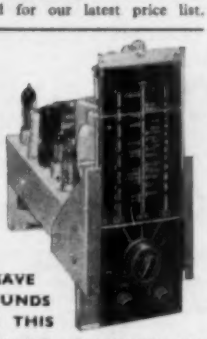
Post and Pkg. 5/-.

LARGE STOCK OF HI-FI EQUIPMENT

Amplifiers, Speakers, etc. Wharfedale, W.B., Goodmans, G.E.C., Leak, Rogers, RCA., Quad, etc.

20,000 VALVES IN STOCK

Send for our latest price list.



SAVE POUNDS ON THIS

6-VALVE RADIOGRAM CHASSIS COMPLETE WITH VALVES

Famous Manufacturer's Surplus. 6-valve, 3-wave Superhet. 13-50 m. short, 200-550 m. medium, 1,000-2,000 m. long. Brand new Mullard valves: ECH42, EF41, L63, EB41, 6V6 g.t., EZ40 and finest quality components. Gram., switch, 465 Kc/s I.F. tone control, three-colour dial. Overall size 13½ × 8in., height 12½in. Aperture required for dial and controls 11 × 3½in. Complete with valves, output trans., knobs., etc.

LASKY'S PRICE £10.19.6

Carriage and packing 7/6 extra.

5-VALVE RADIOGRAM CHASSIS

A.C. mains, 3-wave superhet. Large full vision dial, 11½ × 4½in. Overall dimensions 14 × 6 × 7in. Valve line-up: 12AN8, 6BA6, 6AT6, 6BW6, 6X4.

LASKY'S PRICE, complete with valves, Carr. 7/6. **£9.19.6**

Table Cabinet for above, complete with 6½in. P.M. speaker 49/9

LASKY'S FIRST AGAIN!

We proudly announce a

NEW BATTERY PORTABLE FOR HOME CONSTRUCTION ON PRINTED CIRCUIT

Utilises all latest innovations, giving simplicity of construction with fine quality. 11 STAR FEATURES make this superb new design undoubtedly the finest Portable Radio ever offered to the home constructor.

PEAK VALUE FOR MONEY has been obtained without any sacrifice of quality or design. Use of the printed circuit completely eliminates wiring errors.

- ★ PRINTED CIRCUIT, size 7½in. × 2½in.
- ★ 4-valve Superhet, med. and long waves.
- ★ Low consumption Valves. Double Battery Life.
- ★ Ferrite Rod Internal Aerial.
- ★ 3 or 5in. P.M. Moving Coil Speaker (your choice).
- ★ Brand New T.C.C. Capacitors.
- ★ Automatic Volume Control.
- ★ New Style Contemporary Cases.
- ★ Alternative Styles of Cases.
- ★ Lightweight and Handsome Appearance.
- ★ Every Component available separately.

CAN BE BUILT FOR

£7.7.0 approx.

The most up-to-date Portable available. We regret that at time of going to press illustrations could not be included.

SEND FOR ILLUSTRATIONS with circuit diagram, assembly data, all instructions and full shopping list. Price 1/6 post free.

DEMONSTRATION MODELS AT BOTH OUR ADDRESSES

MAKERS' SURPLUS TV COMPONENT BARGAINS

WIDE ANGLE 36 mm.

Line E.H.T. trans., ferrox-cube core, 9-16 kV.	25/-
Scanning Coils, low imp. line and frame	25/-
Ferrox-cube cored Scanning Coils and Line Output Trans., 10-15 kV, EY51, winding Line Trans. incorporates width and linearity control. Complete with circuit diagram, the pair.	50/-
Frame Output Transformer	6/6
Scanning Coils low imp. line and frame	17/6
Frame or line block osc. transformer	4/6
Focus Magnets Ferrox-dure	19/6
P.M. Focus Magnets, Iron Cored	19/6
Duomag Focalisers	22/6
200 m/a. Smoothing chokes	15/-
Electromagnetic focus coil, with combined scan coils	25/-

STANDARD 35 mm.

Line Output Transformers. No. E.H.T.	12/6
Line Output Transformers 6.9 kV. E.H.T. and 6.3 v. winding. Ferrox-cube	19/6
Scanning coils. Low imp. line and frame	12/6
Ditto by Igranic	14/6
Frame or line blocking oscillator transformer	4/6
Frame output transformer	7/6
Focus Magnets:	
Without Vernier	12/6
With Vernier	17/6
Focus Coils, Electromagnetic	12/6
200 m/a. Smoothing Chokes	10/6

LATEST BRENELL TAPE EQUIPMENT

DECK. 3-speed, 3 motors, record and play back, **18 Gns.**

AMPLIFIER Mk. II, 5 watts, for use with 3 ohms speaker. Magic eye. **18½ Gns.**

Suitable Carrying Case, **£5.18 0**

Write for full details.

RECORDING TAPE

SPECIAL OFFER. Magnetic Recording Tape, kraft base. On Cyldon metal spools:
1,200ft., 11/6; 600ft., 7/6.
On plastic spools:
1,200ft., 12/6; 600ft., 9/6.

PURETONE TAPE on plastic spool 1,200ft. **14/11.**

Post 1/- extra.

All makes of Tape stocked including the new thin long-playing. Also Spools.

LASKY'S (HARROW RD.) LTD.

LASKY'S RADIO

42 TOTTENHAM COURT ROAD, W.1.
(Between T.C.R. and Goodge St. Stns.)
MUSeum 2605

370 HARROW ROAD, PADDINGTON, W.9.
(Opposite Paddington Hospital)
CUNningham 1979

Open all day Saturday. Early closing Thursday (both addresses)

ALL MAIL ORDERS TO HARROW ROAD PLEASE

Phone: LAD 4075

UNDOUBTEDLY THE BEST VALUE YET OFFERED

Stern's "fidelity" Tape Recorder

- Will play the new pre-recorded tapes
- Provides 2 hours playing time at 3¾in. or 1 hour at 7½in. per second
- Will take all standard reels up to 1,200ft.
- Extension speaker sockets are provided
- Has dual input channels for mixing
- Monitoring provided for

PRICE COMPLETE READY FOR USE £43

TERMS: £11 Deposit and 9 months of £3/18/3, or £21/10/- Deposit and 12 months of £1/19/10. Carr. and ins. is £1/10/- extra, but we return £1 on return of packing case.

GUARANTEED FOR 12 MTHS. (B.V.A. VALVES 90 DAYS)

SEND S.A.E. FOR ILLUSTRATED AND DESCRIPTIVE LEAFLETS

The following items form complete Recorder

THE TRUVOX MODEL TR7U TAPE DECK

3 Shaded-Pole motors. Drop-in Tape Loading. Push Button Control. Separate Push Button Brake. Fast forward and fast reverse. Silent drive eliminating Wow and Flutter. Half Track working and 2 speeds, 3¾in. and 7½in. per sec. Positive Azimuth Adjustment. Overall size only 14½ x 12¾in. Available for £23/2/-.

THE MODEL T.R.I./F. AMPLIFIER

Has been expressly designed to meet the requirements of enthusiasts for fidelity reproduction, and in particular to CORRECTLY operate the above TRUVOX DECK. It is supplied complete with a matched Elliptical 3 ohm P.M. Speaker, it incorporates an efficient Tone Control arrangement and has a Magic Eye Indicator (Operative on Record). A Co-axial Socket is also incorporated for MONITORING on Record, and this can also be used to feed an external amplifier. The Amplifier can also be used for high quality reproduction of gramophone records direct from a gram unit. Available for £14/14/-.

HOME CONSTRUCTORS ! ! YOU CAN BUILD THE COMPLETE RECORDER FOR £40/-/-

TERMS: £10 Deposit and 9 months of £3/13/4, or £20 Deposit and 12 months of £1/17/1.

The Truvox TAPE DECK and the Quality Amplifier are supplied tested and ready for use, and the actual assembly of the Tape Recorder is extremely simple, involving only a few connections. Step-by-step connection chart is supplied for this purpose.

If you have your own Cabinet WE WILL SUPPLY: The TRUVOX TAPE DECK, the TAPE AMPLIFIER, MATCHED SPEAKER, and 1,200ft. of E.M.I. TAPE for £33/10/- plus £1/10/- carr. and ins., £1 of which is refunded on return of case.

TERMS: £8/8/- Deposit and 9 months of £3/1/4, or £16/15/- Deposit and 12 months of £1/11/1.

ACOS CRYSTAL MICROPHONE MODEL MIC.33.1 Price £2/10/-.

1,200 ft. REEL OF SCOTCH BOY or E.M.I. MAGNETIC RECORDING TAPE. Price £1/15/-.

PORTABLE ATTACHE CASE

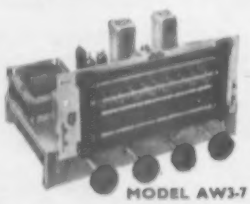
Is a neat, compact and attractively finished case, being covered with maroon rexine and having an ivory coloured speaker escutcheon. It contains concealed pockets to accommodate the Microphone, Mains Lead and a spare 1,200ft. reel of tape. Price £5.

Modernise your old Radiogram

WE OFFER the latest 3 SPEED AUTOCHANGERS with modern RADIOGRAM CHASSIS and matched P.M. SPEAKERS at REDUCED PRICES. (H.P. Terms available.) A good varied selection is available . . . SEND S.A.E. for full DETAILS.

TWO REALLY GENUINE PRICE REDUCTIONS

A BULK PURCHASE ENABLES US TO OFFER these RECEIVER CHASSIS at SUCH LOW PRICES. Each is BRAND NEW and FULLY GUARANTEED.

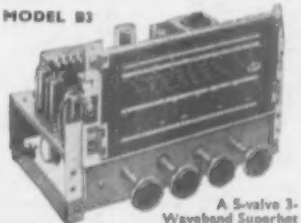


MODEL AW3-7

A 7-valve 3-waveband superhet chassis having a Push-Pull stage for approximately 6 watts output. PRICE £12-19-6

H.P. TERMS: Deposit £6/9/9 and 8 monthly payments of 18/9. Plus 7/6 carr. & ins.

MODEL B3



A 5-valve 3-Waveband Superhet employing Negative Feedback over entire Audio Stages and having a single valve type 6BW6 output for approximately 4 watts.

H.P. TERMS: Deposit £5/15/6 and 7 monthly payments of 17/6. PRICE £11-11-0 Plus 7/6 carr. & ins.

THESE THREE CHASSIS HAVE "GRAM" POSITION and are IDEAL REPLACEMENT CHASSIS FOR THAT "OLD RADIOGRAM"—Send S.A.E. for complete details.

THE ARMSTRONG FC48

A high-quality replacement Radio or Radiogram Chassis having provision for an FM Feeder Unit and incorporating separate BASS and TREBLE CONTROLS. PRICE ASSEMBLED and READY FOR USE £25/2/0

(Plus 7/6 carr. and insurance.)

TERMS: £6/6/- Deposit and 9 months of £2/6/- or £12/11/- Deposit and 12 months of £1/3/3.

Open Monday to Friday 9 a.m.—6 p.m. Saturday 9 a.m.—1 p.m.

STERN RADIO LIMITED

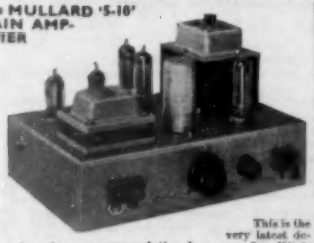
AMPLIFIERS
PRE-AMPLIFIERS

HIGH FIDELITY FOR THE HOME CONSTRUCTOR

TUNING UNITS
RADIO RECEIVERS

—COMPLETE KITS OF PARTS FOR THE "Hi-Fi" ENTHUSIAST—

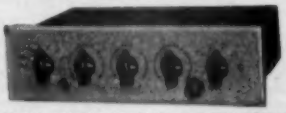
The MULLARD '5-10' MAIN AMPLIFIER



This is the very latest design and needs no recommendation from us. Our Kit is complete to Mullard's specification, including the latest GILSON ULTRA LINEAR OUTPUT TRANSFORMER and the entire MULLARD Valve line up. ALL SPECIFIED COMPONENTS are supplied. **PRICE OF COMPLETE KIT OF PARTS £11/11/0**
(Plus 5/- carr. and ins.).

STERN'S "fidelity" PRE-AMPLIFIER TONE CONTROL UNIT

"A design for the music lover"



Briefly it has inputs for all types of MICROPHONES, HIGH and LOW GAIN PICK UPS and a RADIO TUNING UNIT. It incorporates (a) GRAM EQUALISING CONTROL. (b) STEEPCUT FILTER. (c) Continuously variable BASS and TREBLE CONTROLS and a variable OUTPUT CONTROL which enables its use with any type of Amplifier.
PRICE OF COMPLETE KIT OF PARTS £6/6/0
(Plus 5/- carr. and ins.). WE ALSO OFFER IT ASSEMBLED, READY FOR USE, £8/-/-.
(Plus 5/- carr. and ins.)

STERN'S HIGH QUALITY 8-10 WATT POWER AMPLIFIER

Comprises the MAIN AMPLIFIER of our very popular 8-10 watt design, which we have modified with the express purpose of its use with the "fidelity" PRE-AMPLIFIER illustrated alongside. TWO 6V6's are used in push-pull and the resultant reproduction is genuinely in the HIGH fidelity class yet the total cost is ridiculously low.
PRICE OF COMPLETE KIT OF PARTS £7/7/0
(Main Amplifier only). (Plus 5/- carr. and ins.)

THE full SPECIFICATION and BUILDING INSTRUCTIONS for these three Units are available for 1/6 each. THEY include COMPONENT PRICE LISTS and simple "wire-to-wire" PRACTICAL DIAGRAMS.

SPECIAL PRICE REDUCTIONS . . . FOR PURCHASERS OF A COMPLETE "Hi-Fi" AMPLIFIER

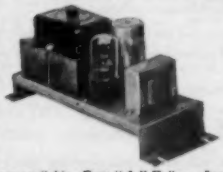
WE WILL SUPPLY (a) COMPLETE KIT OF PARTS to build THE MULLARD "5-10" MAIN AMPLIFIER and the STERN'S "fidelity" PRE-AMPLIFIER-TONE CONTROL UNIT for **£16/16/-** (plus 7/6 carr. and ins.), or we will supply THE TWO UNITS MADE UP and READY FOR USE for **£19/19/-** (plus 7/6 carr. and ins.).
Terms: Deposit **£9/19/6** and 12 monthly payments of **16/7**, or **£5** Deposit and 9 monthly payments of **£1/16/7**.
(b) COMPLETE KIT OF PARTS to build the HIGH QUALITY 8-10 WATT POWER AMPLIFIER and the "fidelity" PRE-AMPLIFIER-TONE CONTROL UNIT for **£13** (plus 7/6 carr. and ins.) or we will supply **THE TWO UNITS MADE UP and READY FOR USE for £15/15/-** (plus 7/6 carr. and ins.).
Terms: Deposit **£7/17/6**. 10 monthly payments of **17/9**, or **£4** Deposit and 9 monthly payments of **£1/8/9**.
QUALITY OF THIS NATURE HAS NEVER BEFORE BEEN OFFERED AT SUCH LOW COST.

AN F.M. TUNING UNIT for the HOME CONSTRUCTOR

STERN'S "fidelity." A well designed unit that can be completely built for
£10/0/0

A design comprising a 5-valve line up, using the latest type valves and incorporates the MULLARD PERMEABILITY TUNING HEART and a "Magic Eye" Tuning Indicator. The performance of this Tuner is genuinely up to the new standard of similar Units now being offered at about £50. Attractively finished in "Hammered gold." The complete SPECIFICATION and BUILDING INSTRUCTIONS are available for 1/6, "wire-to-wire" Diagrams are included. All Components are available for sale separately. **WE SUPPLY THIS TUNER ASSEMBLED and READY FOR USE.** Terms Deposit £7/5/- and 9 monthly payments of **19/4**, or **£14/10/0**
£3/18/- Deposit and 9 months of **£1/5/11**.
A design for a **COMBINED AM-FM TUNER** precisely similar in appearance to the above will be available at end of June. The HOME CONSTRUCTOR will be able to build this for **£13/10/-**. It provides complete coverage of the F.M. Waveband, and the MEDIUM WAVE-BAND, hereby giving a good selection of foreign stations.

STERN'S POWER SUPPLY UNITS



These units are fully smoothed with all output connections terminated to connecting blocks, thereby enabling ease of connecting to a Radio Tuner Unit or Amplifier, etc. Overall size is 9½in. × 3½in. × 4½in. Two Units are available. **Type "A" Unit** . . . Incorporates type 6X5 Valve and provides 250-300 volts at up to 70 mA. and 6.3 volts at 3½ amps.
PRICE OF COMPLETE KIT OF PARTS £2/9/6
ASSEMBLED AND READY FOR USE £2/17/6
(Carriage and insurance 2/6 extra).

TYPE "B" UNIT. Incorporates type EZ81 valve and provides 250-300 volts at up to 100 mA. and 6.3 volts at 3½ amps.
PRICE OF COMPLETE KIT OF PARTS £2/15/0
ASSEMBLED AND READY FOR USE £3/3/0
(Carriage and insurance is 2/6 extra).

The WIRING DIAGRAM IS AVAILABLE SEPARATELY FOR 9d.

STERN'S "COMPACT 5" AMPLIFIERS

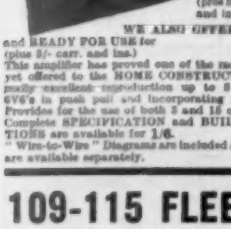
EXPRESSLY DEVELOPED FOR VERY HIGH QUALITY REPRODUCTION OF GRAM. RECORDS AND PARTICULARLY SUITABLE FOR HIGH QUALITY REPRODUCTION OF THE F.M. TRANSMISSIONS: TWO MODELS ARE AVAILABLE:

The "Compact 5-2"
A 2-stage high sensitivity amplifier having SEPARATE BASS and TREBLE CONTROLS and designed to give up to approx. 5 watts with very pleasing quality. **PRICE £5/15/-** (plus 5/- carr. and ins.).

The "Compact 5-3."
A 3-stage version of the "5-2" model but in this case having an additional stage and incorporating negative feedback. **PRICE £6/16/-.** (plus 5/- carr. and ins.)

The Amplifiers are compact and very attractively designed, having a Bronze/Gold finish with a fully engraved front panel by which the entire Amplifier is conveniently mounted into a Cabinet, occupying no more space than a conventional Tone Control Unit. **Fully described in our Leaflets.**
POWER SUPPLY. A separate small Unit is available and this in addition to supplying power to the Amplifier has additional power available for RADIO TUNING UNIT, etc. **PRICE £2/10/-.**

A COMPLETE KIT OF PARTS to BUILD STERN'S "HIGH QUALITY" 8-10 WATT AMPLIFIER



Has power supply available for Radio Tuning Unit.
Price of COMPLETE KIT OF PARTS **£7/10/0**
(plus 5/- carr. and ins.)

WE ALSO OFFER IT ASSEMBLED and READY FOR USE for **£9/10/0**
(plus 5/- carr. and ins.)
This amplifier has proved one of the most popular models yet offered to the HOME CONSTRUCTOR. It provides really excellent reproduction up to 8 watts, employing 6V6's in push pull and incorporating negative feedback. Provides for the use of both 3 and 15 ohm speakers. The Complete SPECIFICATION and BUILDING INSTRUCTIONS are available for 1/6.
"Wire-to-Wire" Diagrams are included and all Components are available separately.

STERN'S BATTERY PORTABLE for the HOME CONSTRUCTOR

This is a completely NEW DESIGN and we cannot at the time of going to press produce an illustration. It incorporates the NEW "ECONOMY" MINIATURE VALVES, and these have about half the battery consumption of the standard valve line-up normally incorporated in this type of Portable set—batteries will therefore last about TWICE AS LONG. The set comprises a 4-valve Superhet design covering both LONG and MEDIUM WAVEBANDS and incorporates a Goodmans 5in. PM Speaker. Tone therefore is very good whilst volume and station selection is excellent. Accommodated in a robust but very attractive rexine covered ATTACHE CASE.

THE COMPLETE RECEIVER including ATTACHE CASE can be built for **£8/12/6**
The ASSEMBLY MANUAL which contains "wire-to-wire" diagrams is available for 1/6.
ALL COMPONENTS are available for sale separately.

EXCEPTIONAL OFFER FOR CASH ONLY

This latest B.S.R. MONARCH 3-SPEED AUTOCHANGER is offered for **£7/15/0** (plus 5/- carr. and ins.)

- These units will autochange on all three speeds, 7in., 10in. and 12 in.
- They play MIXED 7in., 10in. and 12in. records.
- They have separate sapphires for L.P. and 78 r.p.m., which are moved into position by a single switch.
- Minimum baseboard size required 14 × 11½in., with height above 5½in., and height below baseboard 2½in. A bulk purchase enables us to offer these BRAND NEW UNITS at this exceptional price.

The latest **COLLARO RC54 3-SPEED AUTOCHANGER.** This is a "mixer" unit and incorporates the "Studio G" Crystal Pick-up. **£9/19/6.** H.P.: £5 dep. and 7 months at 17/2.

WE ALSO HAVE IN STOCK THE COLLARO MODEL 2010 FX TRANSCRIPTION RECORD PLAYER. S.A.E. FOR FULL DETAILS.

The B.S.R. Model TU.8 3-SPEED RECORD PLAYER

Supplied complete, including the new lightweight "Turnover" type Crystal Pick-up, **£4/12/6.**
Or we supply the 3-speed motor and Turntable for **£2/15/-.**

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RADIO & RADIOGRAM CHASSIS

Superhet. Chassis of Latest Design and Technique

General Specifications applicable to all models

Mains: A.C. 200/250 volts 50 cycles only.
Dial: Suitably lit multi-coloured glass dial of the horizontal type.
Tuning Drive: Slow motion by means of glass-cored Nylon cord.
A.V.C.: Full provision of Automatic Volume Control. Negative feed-back from output transformer secondary.
Sockets: Sockets provided for Aerial, Earth, Gram. Pick-up and Extension Speaker. Connections provided to Gram. Motor controlled by Chassis On/Off switch.
Inductances: All inductances have an exceptionally high Q value.
Audio Section: The Audio Section is designed for first rate reproduction on Radio and Gramophone. The tone controls have been given an extra wide range to embrace all types of recordings.

CAT. NO. CR/A: 5-valve Superhet, 3 wavebands. **12 Gns.**

CAT. NO. CR/B: 7-valve Superhet with push-pull output, 3 wavebands. **16 Gns.**

Packing and Carriage on Models CR/A and CR/B, 12/6.

CAT. NO. CR/AFM47: 7-valve Superhet with F.M./VHF Band (4 wavebands). **23½ Gns.**

CAT. NO. CR/AFM49/PP: 9-valve Superhet with F.M./VHF Band (4 wavebands). Push-pull output including 2 loudspeakers. **26 Gns.**

Packing and Carriage on Models CR/AFM47 and CR/AFM49/PP, 15/

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RADIOGRAM DROP-IN UNITS

These are fully guaranteed Radiograms consisting of Receiver Chassis, Auto Record Changer and matching loudspeaker mounted on a light-weight frame with polished top panel. Needs only fixing inside suitable cabinet to become high quality Radiogram. Offered in two different models.

CAT. NO. UNIT/A55
Chassis as type CR/A described elsewhere. 5-valve Superhet, 3 wavebands. **29½ Gns.**

CAT. NO. UNIT/AFM47
Chassis as type CR/AFM47 described elsewhere. 7-valve Superhet with F.M./VHF Band. **37½ Gns.**

Both units are fitted with latest BSR FOUR-speed Auto Changer.

Packing and carriage 20/-.

HIGH QUALITY BUREAU-TYPE CABINET TO SUIT EITHER UNIT, **15 Gns.**

★ CABINET

CAT. NO. CAB/02
A well-designed Bureau-type cabinet in a medium size. Veneered in a highly figured Walnut. Outside dimensions, length 29½in., depth 16in., height 32in. Sloping control panel on right hand side approx. 13in. × 10½in. Removable baseboard on right hand side approx. 12½in. × 13in. Large record compartment located inside the cabinet, above gram motor.

CASH ONLY **12 Gns.**

Packing and carriage 20/-.

★ PORTABLE TAPE RECORDER

CAT. NO. TR/A
A superb High-Fidelity instrument incorporating the latest TRUVOX Tape Deck. In a beautifully fitted moroccan grained carrying case, this Tape Recorder is the very finest of its class, regardless of price.
TAPE DECK: TRUVOX model TR7U. Twin track with R.S.S. scene of recording. Two speeds, 7½in. (one hour for 1,200ft. reel), and 3¾in. (2 hours for 1,200ft. reel). Full press-button control. Fast forward and rewind. Electro-magnetic braking. **44 Gns.**

PACKING AND CARR.: Payable in advance with order —25/-.

★ PORTABLE TAPE RECORDER (KIT FORM)

CAT. NO. TR/A/KIT.
A complete kit consisting of:—
FULLY FITTED CARRYING CASE
TAPE DECK—TRUVOX TR7U
TAPE RECORDER AMPLIFIER
MICROPHONE—ACOS 33-1
SPEAKER—7in. × 4in. Elliptical
MAGNETIC TAPE REEL
To the same specifications and similar to those used in the Portable Tape Recorder (Cat. No. TR/A), this complete kit offers the home builder all that is required to construct a portable Tape Recorder of the finest quality. **42 Gns.**

PACKING AND CARRIAGE: Payable in advance with order—25/-.

★ F.M./V.H.F. TUNERS

CAT. NO. FMT/A
An F.M./V.H.F. Tuner Unit with automatic Magic Eye Tuning, fitted in a high grade dark Walnut cabinet. Adaptor is self-powered and completely self-contained.
CIRCUIT DETAILS: SIX Valves and 10 Tuned Circuits for maximum sensitivity and best signal to noise ratio.
Packing and Carriage 12/6. **16½ Gns.**

CAT. NO. FMT/B
An F.M./V.H.F. Tuner Unit in chassis form, suitable for building into existing Radiograms or Radio Receivers. Adaptor is self-powered. Socket for additional Magic Eye fitment is provided in the Chassis.
Packing and Carriage, 12/6. **£13-15-0**

★ LOUDSPEAKERS

Permanent Magnet Type (Voice Coil Impedance 3 ohms).
CAT. NO. LS/10/PM: 10in. diameter, Flux density 8,500 lines.
PRICE: CASH ONLY £1/10/-.
PACKING AND CARR.: 3/-.
CAT. NO. LS/8/PM: 8in. diameter, Flux density 8,500 lines.
PRICE: CASH ONLY £1/10/-.
PACKING AND CARR: 3/-.
CAT. NO. LS/74/PM: Elliptical 7in. × 4in. Flux density 7,500 lines.
PRICE: CASH ONLY £1/1/-.
PACKING AND CARR.: 3/-.
Electrostatic "Treble" type, imported (suitable for accentuating treble response, particularly on F.M./V.H.F. reception)
CAT. NO. ELEC/LSH 75: PRICE, CASH ONLY 12/6.
Packing and carriage free.
CAT. NO. ELEC/LSH13: PRICE, CASH ONLY 17/6.
Packing and carriage free.
CAT. NO. ELEC/LSH100: PRICE, CASH ONLY £1/1/-.
Packing and carriage free.

★ BUREAU CABINET

CAT. NO. CAB/03

A magnificent Bureau-type Cabinet of the very highest quality in specially selected Walnut veneered exterior. Light Sycamore interior with Rexine lining to match. Outside dimensions, length 34in., depth 17½in., height 33in., sloping control panel on right-hand side approx. 16in. × 10½in. Removable baseboard on right side approx. 15½in. × 15in. Two full-sized felt lined compartments in the lower half. **16½ Gns.**

Packing and Carriage payable in advance with order—25/-.

★ MULTI-SPEED AUTOMATIC RECORD CHANGERS

All automatic Record Changers are of the latest type and unused.

CAT. NO. RC/A: This is the latest, Multi-speed changer incorporating 16 r.p.m. for "talking-books," and arrangement for manual control. Fitted with high fidelity Crystal Turnover Pick-up Head. A.C. mains 200/250 volts, 50 cycles only. **£9 - 15 - 0**
PRICE: CASH ONLY
PACKING AND CARR.:—12/6.

CAT. NO. RC/B: Latest GARRARD RC88 model, fitted with GC-3 Crystal Turnover Pick-up Head. A.C. 200/250 volts, 50 cycles.
PRICE: CASH ONLY **£13 - 0 - 0**
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Chassis mounting or **drop-thro'.** Pri. 110-150 v. Sec. 250-0-250, 250 mA., 6.3 v. 7 amp., 6.3 v. 0.5 amp., 5 v. C.T., 2.5 amp. 4 v. amp. P. & P. 2/6. **32/6.**

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Mains transformer, fully impregnated. Input 210, 220, 230, 240. Sec. 350-0-350 100 mA. with separate heater-transformer. Pri. 210, 220, 230, 240, sec. 6.3 v. 2 amp., 6.3 v. 3 amp., 4 v. 6 amp., and 5 v. 2 amp., **30/-.** P. & P. 5/-.

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6½in. M.E. Speaker, 1,000 ohm field, 15/-.

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Twin Gang .0005 Tuning Condenser 5/-. With trimmers, **7/6.**

Twin Gang .0005, with feet, size 3½ × 2 × 1¼in., **6/6.**

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T.V. Coils, moulded former, iron-cored wound for re-winding purposes only. All-can 1⅝ × 1¼in., 1/- each. 2 iron-core All-can 2¼ × 2in., **1/6** each. The above coil formers are suitable for the "Wireless World" F.M. tuner.

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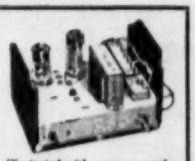
SUITABLE ANY T.V. using lower side band NO ALTERATIONS TO SET



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Less power supply **£2/19/6.** P. & P. 2/6.

BAND III CONVERTER KIT

comprising 5 channel tuner, mains transformer, metal rectifier, electrolytic, 2 valves 12AT7 and EF80 and all necessary components for A.C. mains operation. Complete with conversion data, **£2/5/-.** P. & P. 2/6.

P.M. SPEAKER. 6½in. closed field, **18/6.** 8in. closed field, **20/6.** 10in. closed field, **25/-.** 12in. closed field, **25/-.** P. & P. on each, 2/-.

EXTENSION SPEAKER in polished walnut, complete with 8in. P.M. P. & P. 3/-. **94/6.**

B.S.R. MONARCH three speed automatic changer, current model. **Brand new. Will take 7in., 10in., or 12in. records mixed. Turnover crystal head. A.C. mains 200-250. Pre-Budget Price while stocks last. £7/15/-.** P. & P. 3/-.

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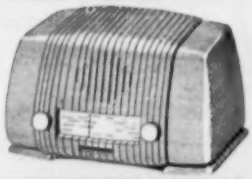
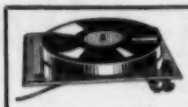


3 valve plus metal rectifier, A.C. mains 200-250 v. Medium and long waves. In pastel blue or brown. Valve line-up: 2 VR85s and VT52. Size 15½in. long by 9in. high by 7in. deep. **£3/19/6.** P. & P. 4/6.



3-speed TRANSCRIPTION MOTOR

BY FAMOUS MANUFACTURER

Complete kit of parts comprising accurately balanced precision made heavy turntable with rubber mat, large constant speed condenser starting motor, base plate. Can be assembled in half an hour. A.C. Mains 200/250 v. Fully guaranteed. Parts sold separately.

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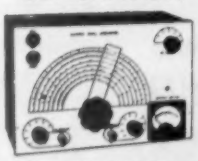

Coverage 120 Kc/s-84 Mc/s.

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Or 34/- deposit, 3 payments of 25/-. P. & P. 4/6 extra.

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As above, but complete with line and frame blocking transformers, 5 Henry 25 mA. choke, 100 mfd. and 150 mfd. 250 wkg. 200 mA. A.C. ripple. **£2/9/6.** P. & P. 3/-.

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3 speed automatic changer. 10 Records, turnover crystal head, brand new, current model. A.C. mains 200/250 v. (list price £14/10/-). **£8-19-6**

P. & P. 5/-.

Hire purchase available.

Standard Wave Change Switches, 4-pole, 3-way, 1/9; 5-pole, 3-way, 1/9; 3-pole, 3-way, 1/9; 9-pole 3-way, 3/6. Miniature type, long spindle, 3-pole, 4-way, 4-pole 2-way and 4-pole 2-way, 2/6 each. 2-pole 11-way, twin wafer, 5/-; 1-pole 12-way single wafer, 5/-. P. & P. 2d.

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Wide Angle P.M. Focus Units. Vernier adj. state tube, 15/-.

P.M. Focus Unit for Mullard tubes with vernier adjustment. P. & P. 2/-. 15/-.

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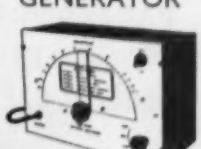

Coverage 40 Mc/s.-70 Mc/s.

A.C. Mains 200/250 v. **£3 - 19 - 6**

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Completely Fitted comprising 12in. Axiom No. 150 Mk. II Speaker. The Acoustic Resistance Unit and Cabinet to Messrs. Goodmans specification. Lined and Quilted with 1in. cotton felt and constructed of ¾in. Weyrock.
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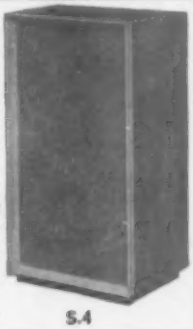
Also in Corner Cabinets 27/6 extra.
Write for catalogue of cabinets for Records—Equipment—Speakers.



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1C5GT	9/6	6F22	7/6	10C1	12/6	EF42	13/6	PY81	11/6
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1L4	6/6	6F24	4/-	10F1	12/6	EF80	12/6	PY83	12/6
1LD5	6/9	6H6	3/6	10F9	12/6	EL2	12/6	R19	13/6
1N5	10/6	6J50/GT	5/-	10P13	11/6	EL33	7/6	RP220	6/9
1P14	12/6	6J5M	6/6	12A6	6/9	EL41	11/6	SP22	6/-
1R5	8/-	6J6	7/6	12AH7	6/9	EL84	10/-	U18	9/-
1S5	7/6	6J7G	6/6	12AT7	9/6	EL91	5/-	U22	8/-
1T4	7/6	6J7M	6/6	12AU7	9/6	EM34	11/6	U25	11/6
1U4	8/-	6K7G	5/9	12AX7	10/-	EM80	9/-	U26	10/-
1U5	8/-	6K7M	5/9	12BE6	10/-	EY51	12/6	U404	11/6
2X2	4/-	6K70T	6/9	12H6	5/-	EY86	14/6	UAF42	12/6
3A4	7/-	6K7	6/9	12J5	6/-	EY91	7/-	UB41	8/-
3Q4	9/6	6K8G	8/9	12J7	9/6	EZ40	10/-	UBC41	11/-
3Q5	10/-	6K8GT	9/6	12K7	9/6	EZ41	11/-	UCH42	11/-
3S4	8/6	6L6G	9/-	12K8	11/-	EZ80	10/6	UF41	11/6
3V4	8/6	6L7M	7/6	19Q7	9/6	K1148	2/-	UL41	11/6
4D1	3/-	6N7	7/-	125G7	2/6	FW4/500	10/-	UT41	10/6
4S	8/-	6Q7G/GT	9/-	12SG7	7/6	GZ32	12/6	VR21	3/-
5Z4G	9/6	6SA7GT	8/-	12SH7	5/6	H30	5/-	VR53	6/6
5U4G	8/6	6S07	7/6	12SJ7	5/6	HL2	5/6	VR54	2/-
5Y3GT	8/6	6SH7	6/-	12SK7	6/6	HL23DD	4/-	VR55	7/6
5Z4G	8/9	6S7GT	8/-	12SQ7	9/6	HL23DD	8/-	VR56	6/-
6A7	11/6	6SK7	5/6	14D8	5/-	HP211C	6/9	VR57	8/-
6A8GT	10/6	6SL7	8/-	20L1	12/6	HP4101	7/-	VR65	3/6
6AC7	6/6	6SN7	8/-	35L6GT	9/6	IC8	6/6	VR105A	2/3
6AG5	6/6	6U7G	9/3	35U4GT	10/-	IR5	7/-	VR106	2/3
6AK5	6/6	6U8	9/-	35Z5G	9/9	LK35	8/6	VR91	3/6
6AL5	7/-	6U49T	15/-	35Z4G	9/6	KT8	5/-	VR105TL	7/6
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6BW6	8/6	7C6	9/-	DM70	10/6	M700	13/-	VS70	3/-
6BW7	12/6	7H7	8/-	EAF42	11/6	P41	6/-	VT52	3/-
6C4	7/6	7S7	8/6	EB41	9/-	P61	6/9	VT501	6/-
6C8GT	7/6	7S7	9/-	EBC41	11/-	PB15	5/-	VU39	3/9
6C9	6/6	7Y4	8/6	EBF80	15/-	PEN25	6/-	VU84	9/-
6C8	5/-	75	10/6	ECH21	6/6	PEN44	6/6	VU111	3/6
6C9	10/6	77	8/-	ECC91	8/6	PEN220A	7/-	VU120A	3/-
6CH6	9/-	80	8/6	ECC84	14/6	PCC84	13/6	W77	9/6
6D6	7/6	807	6/6	ECC85	12/6	PCF80	12/6	W61	8/-
6D8	7/3	5D8	2/9	ECF82	15/-	PCF82	12/6	X25	10/-
6D6	7/3	9D8	3/9	ECH35	13/6	PCL82	12/6	X66	11/6
6F1	13/6	9001	5/6	ECH42	11/-	PL81	12/6	Y63	9/-

Packing and postage 6d. per valve.

ALPHA 3-VALVE T.R.F. KIT

★ Easy to build. ★ Valves 6A7, 6K7, 6V6GT plus metal rectifier. Full instructions, point to point wiring diagram. Price £5/10/- each. Post and Packing 3/-. Circuit diagram and full shopping list 1/-. All components may be purchased separately.

★ Walnut finished cabinet.

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3-way mounting type
MT1
Primary: 200-230-240v.
Secondarys: 250-0-250 v., 80 M/A 6-6.3 v. 4 amp. 6-4 v. 2 amp. Both tapped at 4 v., each 18/6
MT2
Primary: 200-230-240 v.
Secondarys: 350-0-350 v. 80 M/A 6-6.3 v. 4 amp. 6-5 v. 2 amp. Both tapped at 4 v., each 18/6
MT3
Primary: 200-230-240 v.
Secondary: 20 v. 2 amps.
Taps at 2 v., 4 v., 6 v., 8 v., 9 v., 10 v., 15 v., 18 v., 20 v., 24 v., each 18/6
2/- packing & post on above transformers.

CRT ISOLATION TRANSFORMERS

NR9A 2 volt: NR9B 4 Volt: NR9C 6.3 v.: NR9D 10.9 v.: NR9E 13.3 v. Price 10/6 each, all for use on receivers with own transformer.

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NR15 Input 220/240 v. Output 6.3 v., with 25% and 50% BOOST. Price 17/6 each.

AMERICAN INDICATOR UNIT TYPE BC929A

Brand new, incorporating 3in. tube 3BP1, with mu-metal shield, two 6SN7GT, two 6H6GT, 6X5G, 5Y3, 6030, nine potentiometers, 24 v. aerial switch motor, transformer, and a host of small components. The whole unit, which measures only 8½in. x 8½in. x 12½in., is brand new, enclosed in black crackle box, and can be supplied at price 65/-, plus 5/- postage and packing.

TRANSFORMERS, ETC.

HEATER TRANSFORMERS

230 v. Input 2 volt .5 amp., each	5/-
230 v. Input 2 volt 2.0 amp., each	8/3
230 v. Input 4 volt 1.5 amp., each	5/6
230 v. Input 4 volt 3.0 amp., each	10/6
230 v. Input 5 volt 2.9 amp., each	10/6
230 v. Input 6.3 volt .5 amp., each	5/6
230 v. Input 6.3 volt 1.5 amp., each	8/6
230 v. Input 6.3 volt 3.0 amp., each	9/6
230 v. Input 12 volt, .75 amp., each	8/6

CHOKES

20H, 250 ohms, 65 M/A. Clamp construction, each	6/-
10H, 200 ohms, 80 M/A. Clamp construction, each	8/3
10H, 200 ohms, 150 M/A. Clamp construction, each	13/-
10H, 300 ohms, 40 M/A. Midget Clamp construction, each	5/3

TRANSFORMERS FOR BATTERY CHARGERS

230 v. Input Tapped 6-12 v. 1 amp., ea.	12/6
230 v. Input Tapped 6-12 v. 3 amp. (Both with tap on Primary for 2.5 v. Pilot light), each	18/-

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Designed to adapt common low tension voltages 4 v., 5 v., 6.3 v. at 3 amps., centre tapped and interchangeable, each 7/6

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By Colvern, etc., all with ¼in. spindle. 5 ohms, 100 ohms, 300 ohms, 250 ohms, 500 ohms, 1K ohms, 2K ohms, 10K ohms, 20K ohms, 25K ohms and 50K ohms. All 2/6 each.

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BEC 500 MFD 12 v.	1/9
TCC 25 MFD 25 v.	1/3
DUBILIER 100 MFD 12 v.	1/9
BEC 50 MFD 50 v.	2/-
TCC 25 MFD 50 v.	1/9
TCC 50 MFD 25 v.	1/9
TCC 250 MFD 12 v.	1/6
BEC 250 MFD 25 v.	1/6
BEC 12 MFD 50 v.	1/-
TCC 50 MFD 12 v.	1/9
BEC 250—250 MFD 6 v.	1/9
DUBILIER 50—12 MFD 12 v.	1/9

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Multi Ratio Type, each	6/6
Midget for 3S4 Output, each	4/6
Standard 5,000 ohms, each	4/6
Standard 10,000 ohms, each	4/6
Ignacio Jack Plugs, each	2/3
Bell Lee 7-pin Plug and Socket, each	1/6

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12 volt, 2 amp., each	9/6
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Type with Single Pole Switch.
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With Double Pole Switch 500K ohms and 500K ohms. Price 6/9 each.

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Brand new miniature I.F. Strip size 10¼in. × 2¼in. × 3in. high. Valve line-up: 2-EF92; 3-EF91 and EB91. With circuit.

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Complete with 5BP1 C/R tube and screen. 7 valves—2-6SN7GT, 6G6, 2X2, 6X5G, volume controls, condensers, etc. Ideal for portable 'scope. In black crackle case size 15¼in. × 9in. × 9in. BRAND NEW. 65/-, carr. FREE.

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Special offer of above set, complete with 5 valves, 4-ARP12 and ATP4, with circuit. Range 7.4 to 9 Mc/s. These sets are not guaranteed but are serviceable.

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Containing VCR97 with Mu-Metal Screen: 21 Valves: 12-EF50, 4-6F61, 2-EA50, 2-EB34. Price Pots., Switches, H.V. Cond., Resistors, Mutriced 6/M Dial. Double Deck Chassis and Crystal. BRAND NEW ORIGINAL CASES, 67/6. Carr. 7/6.

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Size 15in. × 8in. × 3in. Complete with 45 Mc/s. Pye Strip, 12 valves, 10-EF50, EB34 and EA50, volume controls, and boxs of Resistors and Condensers. New condition. Modification data supplied.

Price 69/6. Carriage paid.

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Unit contains VCR517 Cathode Ray 6in. tube, complete with Mu-Metal screen, 3 EF50, 6SP61 and 1 6U40 valves, 9 wire-wound volume controls and quantity of resistors and condensers. Offered BRAND NEW (less relay) at 67/6. Fits 7/6 carr. "Radio-Constructor" scope circuit included.

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10 EF50 (Red Sylvania, ex-new units) 6/- each	55/- "
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1R5, 1S5, 1T4, 1S4 or (3S4 or 3V4)	27/6 "
DK96, DF96, DAF96, DL96	32/6 "
6K8G, 6K7G, 6Q7G, 25A6G, 25Z6 (or 25Z6G)	37/6 "
12K8GT, 12K7GT, 12Q7GT, 35Z4GT, 35L6GT (or 50L6GT) ..	37/6 "
12SA7GT, 12SK7GT, 12SQ7GT, 35Z4GT, 35L6GT or 50L6GT	05/- "

TRANSISTORS

OFFERED AT LESS THAN HALF-PRICE

This **Junction Transistor Type P.N.P.** is designed for A.F. application up to 800 Kc/s, and is suitable for use in Radio Control, Signal Tracers, Local Station Receivers, Oscillators, Transistor Voltmeters and Experimental work, etc.

10/- EACH

(complete with Technical Data and Circuits)

ELECTRICAL DATA

Maximum collector voltage	—5 volts
Peak collector voltage	—5 volts
Maximum collector current	—10 mA
Maximum emitter current	—10 mA
Maximum power dissipation	—25 mW

QUARTZ CRYSTALS

TYPE FT243 fundamental Frequencies. 2 pin ½in. spacing.

100 TYPES. 5675 Kc/s. to 8650 (in steps of 25 Kc/s.).

80 TYPES. 5706 Kc/s. to 8240 Kc/s. (in steps of 33.333 Kc/s.).

ALL BRAND NEW **10/-** each

Special price for complete sets of 80 or 120

Above are suitable for regrinding

TYPE FT241A 54th harmonic Crystals. 2 pin ½in. spacing.

80 TYPES AVAILABLE 20 Mc/s.—27.9 M/Mc/s. (in steps of 100 Kc/s.). COMPLETE SETS AVAILABLE.

ALL BRAND NEW **7/6** each

FT241A 200 Kc/s. 10/- each.

Crystal Holders for both Types 1/3 each.

LATEST TYPES NOW IN STOCK

EBC41	10/-	EABC80	10/-	12AT6	8/-	PABC80	15/-
EY51	12/-	ECC85	10/-	12AT7	9/-	6AU6	9/6
EF41	11/-	EF80	10/-	12AU6	9/-	117Z3	9/6
EL41	11/-	ECL80	12/6	12BA6	9/-	12AX7	10/-
EZ40	10/-	PL81	12/6	12BE6	10/-	DK96	9/-
EM34	10/-	PL82	10/-	12AH8	12/6	DL96	9/-
UL41	11/-	PY81	10/-	35W4	8/6	DAF96	9/-
UY41	11/-	KM80	10/-	PCF80	15/-	DF96	9/-
UF41	11/-	6X4	8/-	EBF80	11/6	ECC84	12/6
UCH42	12/6	PY82	10/-	EF85	10/6	6AQ5	10/-
UBC41	10/-	PCC84	12/6	EF89	10/6	PCL82	12/6
DK40	10/-	PCF82	12/6	ECF82	15/-	ECH42	12/6
EF80	10/-	12AU7	9/-	EF86	12/6	5A8	12/6

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1A7GT 1N5GT, 1H5GT, 1A5GT (or 1Q5GT or 3Q5GT) ..... 37/6 Set
10 EF50 (ex-Brand New Units) 5/- each ..... 45/- "
10 EF50 (Red Sylvania, ex-new units) 6/- each ..... 55/- "
6K8G, 6K7G, 6Q7G, 5Z4G, 6V6G ..... 35/- "
1R5, 1S5, 1T4, 1S4 or (3S4 or 3V4) ..... 27/6 "
DK96, DF96, DAF96, DL96 ..... 32/6 "
6K8G, 6K7G, 6Q7G, 25A6G, 25Z6 (or 25Z6G) ..... 37/6 "
12K8GT, 12K7GT, 12Q7GT, 35Z4GT, 35L6GT (or 50L6GT) .. 37/6 "
12SA7GT, 12SK7GT, 12SQ7GT, 35Z4GT, 35L6GT or 50L6GT 05/- "

WE HAVE OVER 50,000 BRITISH AND AMERICAN VALVES AVAILABLE AT VERY LOW PRICES—SEND FOR LISTS.

GARRARD 3-SPEED MIXER AUTO-CHANGER Model RC110

A.C. 200/250. List price £14/13/-. Brand New.

£8/18/6 P. & P. 5/-

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Very latest type "Monarch" in hammered gold finish. 3-speed with RGP37 crystal turnover pick-up. Plays mixed records. Brand new and guaranteed. Listed at £16/10.

£7/19/6, carr. paid.

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Complete with 6 valves: 2 EF36, 2 EF39, 1 EK32, 1 EBC33, 465 I.F.T., ideal for conversion. In absolute new condition. 27/6. P.P. 2/6, with circuit.

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Transmitter section comprising EL32, EF50, VT501, Relay, etc. 12/6. P.P. 2/6

COMPLETE TRANSMITTER RECEIVER with 24 v. power-pack in original transit case. 57/6. P.P. 5/-

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TRANSMITTER/RECEIVER SCR 522

Comprising the well-known BC625 and BC624A Units complete with 17 valves types: 2-832, 2-12AE, 2-12SG7, 2-9002, 9002, 6060, 12J5GT, 12AH7GT, 1903, 6667. The Complete unit is in very good condition having very useful parts including Relays, Transformers, Condensers etc.

Less valves, £3/10/-, carr. paid

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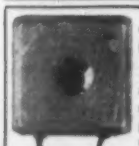

CRYSTAL MICROPHONE INSERTS. Ideal for tape recorders, amplifiers etc., extra sensitive. Supplied in good condition and tested, only 4/6 each. Size only ¾in square.

DEAF AID UNITS. Due to another huge purchase we are again able to offer these units at a fantastically cheap price. Made by famous manufacturer. Complete less only outer case Battery space provided on chassis. Requires 22½ and 1 5 v.

Feature includes: 1. 3 Mullard valves. 2 DF64 and 1 DL66 output 2. Output transformer matched to 30 ohms. 3. Extra sensitive crystal microphone. 4. Built in volume control. 5. Size only 3½ × 1¾in. ONLY 19/6 each.

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COSSOR DOUBLE BEAM OSCILLOSCOPES. Type 3339. These laboratory test instruments are offered in perfect condition, fully reconditioned and tested. Operation 200/250 volt A.C. Main features are: Frequency 6 cps.-2 mc/s. 10 time base positions, sweep 10 cps.-250,000 cps., Y1, Y2 sensitivity 3.6 volts D.C. 1.1 volt RMS, X sensitivity 2.25 volts D.C. Size of tube approx. 4½in. Price only £21 each.

AR.88 RECEIVER SWITCH ASSEMBLIES. 8 wafer 6 position screened assembly supplied brand new in original boxes. A must have spare for this receiver. Price only 17/6 each

Few only geared drive assemblies for this receiver, brand new 10/6 each.

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200 m/amp. 2½in. F.M. M.C.	9/6
1 amp R.F. 2in. F.M. T.C.	6/9
1 amp. R.F. 2½in. PJ. T.C.	5/-
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SPECIAL OFFER GRAM. MOTORS. Garrard 200/250 volt A.C. gram motors, complete with turntables. Adjustable speed from 0 to 45 r.p.m. Can be used for latest type records 33 or 45 r.p.m. A real snip at only 22/6 each

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AMERICAN POWER RHEOSTATS Brand new and boxed. 8 ohm 3.3 amp., 8/6; 8 ohm 2.5 amp., 7/6; 90 ohm. 0.74 amp., 7/6; 200 ohm. 0.35 amp. 5/6.

R.1294 RECEIVERS. Superhetrodyne receiver covering 500-3,000 mc/s. (10-60 cm.). Input impedance 70 ohms. 2 detector stages, 2 L.F. amplifier stages. I.F frequency 13.5 mc/s. Bandwidth 2.5 mc/s. Price £35 each

BRAND NEW BENDIX COMMAND RECEIVERS. Supplied in original carton complete with all valves: 2-12SK7, 2-12SR7, 1-12K8 and 1-12A6, BC453, Q Finer, 190/500 kc/s 69/6. BC XXX, top band, 1.5/3 Mc/s. 85/-, with circuit.

MINIATURE H.T. TRANSFORMER. Input 220/240 volts. Output 200 volt 25 ma. and 6.3 volt 1 amp. 10/6 each. Miniature metal rectifier to match, 7/6 each.

HOURS OF BUSINESS:—9 a.m.—6 p.m. Thursday 1 p.m. Open all day Saturday.

PLEASE PRINT NAME AND ADDRESS CLEARLY. ALSO INCLUDE POSTAGE OR CARRIAGE ON ALL ITEMS

Best Buy at Britain's

METER BARGAINS

RANGE	TYPE	SIZE		PRICE
50 Microamp.	D.C. M/C	2½in.	Flush circular, scaled 0-100	59/6
100 Microamp.	D.C. M/C	2½in.	Flush circular, scaled 0-1,500	39/6
500 Microamp.	D.C. M/C	2in.	Flush square, Weston	27/6
500-0-500 Microamp.	D.C. M/C	2½in.	Flush circular, scaled 100-0-100 V.	25/-
1 Milliamp.	D.C. M/C	2in.	Flush square, Fe/NFe	22/6
1 Milliamp.	D.C. M/C	2½in.	Desk Mounted type	32/6
10 Milliamp.	D.C. M/C	2½in.	Flush circular, blank scale	10/6
100 Milliamp.	D.C. M/C	2½in.	Flush circular	10/6
150 Milliamp.	D.C. M/C	2in.	Flush square	7/6
200 Milliamp.	D.C. M/C	2½in.	Flush circular	10/6
1 Amp.	Thermo-couple	2½in.	Projecting circular	6/9
4 Amp.	Thermo-couple	2in.	Flush square	6/9
20 Amp.	D.C. M/C	2½in.	Projecting circular	7/6
30-0-30 Amp.	D.C. M/I	2in.	Proj. circ., metal cased, car type	5/-
15 Volts	A.C. M/I	2½in.	Flush circular	8/6
300 Volts	A.C. M/I	3½in.	Flush circular	30/-
300 Volts	D.C. M/C	2in.	Flush square	10/6

METER RECTIFIERS. 1 mA. Salford Instruments, **8/6**; and 5 mA., **6/9**; 2 mA., S.T.C., as used in E.M.I. Output Meter, **5/6.**

All are full wave bridge and brand new.

ADMIRALTY COMMUNICATIONS RECEIVER TYPE B.28 (MARCONI CR.100). Frequency range, 60 Kc/s to 30 Mc/s. Self-contained power pack 200/250 volts A.C. 50 cps. Variable Selectivity Crystal Filter. Complete with valves and Air Tested. SUPERB CONDITION. PRICE ONLY £21.
Plus £2 carriage and packing (£1 refunded on return of packing case). Send S.A.E. for full details and illustration.

PANORAMIC ADAPTORS. Visual display of signals on 3in. CR Tube 3BP1. Band width 200 Kc/s. Suitable for receivers with I.F. of 450–475 Kc/s. Operates from 110–230 V. A.C. mains. BRAND NEW, as shipped ex-U.S.A. With instruction manual, **£30.** Suit CR100.

RCA SPEAKER—An 8in. P.M. unit contained in beautiful black crackle cabinet, suitable for AR88, etc. BRAND NEW. Price only **45/-.**

COMMAND RECEIVERS. Complete with 6 metal valves, 3 12SK7, 1 12K8, 1 12SR7 and 1 12A6. Size 5in. x 5¼in. x 11¼in. deep. In very good condition. Less dynamotor. FREE CIRCUIT WITH EACH SET. BC455, 6-9 Mc/s., **25/-.** BC453 (the famous Q5'er), 190–550 Kc/s., **59/6.** BC454, 3–6 Mc/s., **27/6.** BCXXX ("Trawler" band), 1.5–3 Mc/s., **65/-.**

U.S.A. POWER UNITS. 115 v. A.C. input. 1,000 v. 250 mA. output. Complete with two 1616 and 1 spare. Double smoothing. BRAND NEW, **£5/5/-.**

AM POWER UNITS 247. 230 v. A.C. input. 600 v. 200 mA., 6.3 v. 3 amp. output. BRAND NEW, **49/6.**

EDDYSTONE ROTARY POWER UNITS. 12 v. D.C. input. 180 v. 60 mA. output, smoothed and filtered. In grey metal case 12 x 6 x 5in. Weight 16 lb. BRAND NEW, **19/6.**

HEAVY DUTY LT TRANSFORMERS. 230 v. A.C. mains input. Secondary 5-0-5 v. 5-0-5 v., and 5-0-5 v., all at 5 amps., each winding. 5, 10, 15, 20, 25, 30 v. at 5 amps. or other possible combinations. Size 4¼in. x 4¼in. x 6in. high. Weight 12 lb. BRAND NEW, **29/6.**
Primary 230 volt 50 cycle. Two separate secondary windings each 14 volt C.T. 12 amps. 7, 14, 21 or 28 volts 12 amps. or other possible combinations. Weight 24 lb. Admiralty pattern. BRAND NEW, **42/6.**

G.E.C. 200–250 v. A.C. input. 30 v. tapped at 10 v. 36 amps. output. 5½in. x 6in. x 7in. high, weight 24 lbs. **55/-.**

SELENIUM BRIDGE RECTIFIERS. Funnel cooled. 45 v. RMS input. 30 v. 10 amp. D.C. output. BRAND NEW **47/6.**

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A sub-chassis 3½ × 6½ × 2½in. houses a Receiver tuned to the transmitting frequency. Contains TWO 9004 valves. For use in 70 cm. band.

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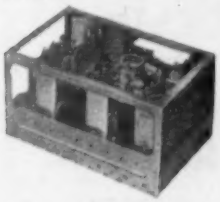

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Suitable for conversion to 2 metres or F.M. Wrotham transmissions.

Valve line-up: (4) EF50. (1) EL32. (2) EF39. (1) EBC33. (1) EA50. Supplied with circuit diagrams.
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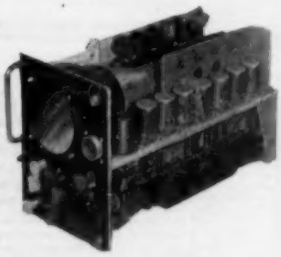

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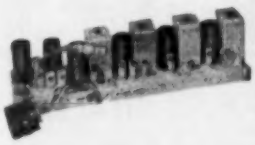

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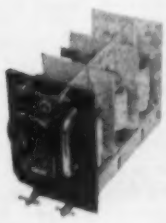
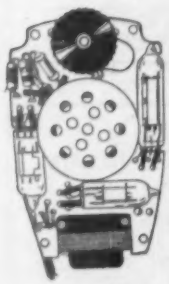


2-3mA MEASUREMENT METER

2-3 mA movements in metal case measuring 4½in. high, 3½in. wide and 5in. deep. 7/6 plus 2/- p.p.

Make a miniature POCKET RADIO



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30 v. H.T. (Type B.119)	4 3

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500 "	2in.	MC/FS	27/6
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5 "	2in.	MC/FS	10/6
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100 "	2½in.	MC/FR	12/6
200 "	2½in.	MC/FR	12/6
500 "	2½in.	MC/FR	12/6
20 Amp.	2½in.	MI/FR	25/-
50	3in.	MI/PR	60/-
50-0-50 Amp	2in.	MC/FS	12/6
15 Volt	2½in.	MI/FR	15/6
20 "	2in.	MC/FS	10/6
40 "	2in.	MC/FS	10/6
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SIGNAL AND NOISE GENERATOR. Television frequencies 20/88 Mc/s. in 4 bands. Crystal controlled. Operating on 115 v. or 80 v. suitable for conversion to 230 v. The few we have left we offer at the very special price of **£6/17/6.**

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AMPLIFIERS. A high fidelity unit with separate Bass and Treble controls, constant impedance attenuator for setting volume level. 15 watt output, for 200/250 v. A.C. mains operation. Ideal for P.A. work, dances, etc. LESS VALVES, **£12/10/-.** Complete with valves, **£15/12/6.** Cge. **12/6.**

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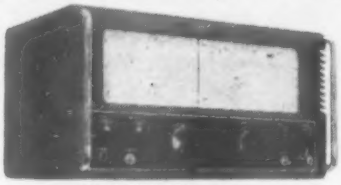

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4 volt	10/6 each Panel and
6.3 volt	10/6 each Solder Tags
10.2 volts	10/6 each
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Ditto with mains primaries 12/6 each.
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HIGH STABILITY. ¼ w., 1%, 2/-. All preferred values 100 ohms to 10 meg.

½ watt	WIRE-WOUND RESISTORS 1/3
10 watt	25 ohms—10,000 ohms 1/6
25 watt	2/-

15,000 ohms—50,000 ohms, 5 w., 1/9; 10 w. 2/3
WIRE-WOUND POTS. 2 WATT LAB. COLVERN ETC.

Pre-set Min. T.V. Type	Standard Size Pots., 2½in.
Knurled Slotted Knob.	Spindle High Grade. All
All values 25 ohms to 50	Values. 100 ohms to 50 K.
K. 2/-, ea. 50 K., 4/-.	5/6; 100K., 6/6.
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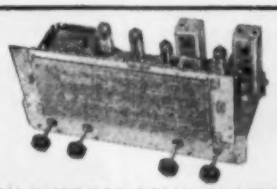

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MATCHED SPEAKERS FOR ABOVE CHASSIS 8in., 19/6; 10in., 25/-; 12in., 30/-.

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Walnut Veneered Playing Desk cut out ready for Plessey, only sold complete with Changer. 10/6 extra.

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AMPLION. 3-speed Single Record unit with Acos 37 Turnover Head, each Sapphire Styius plays 2,000 records. Starting Switch Automatically places Pick-up on records, 7in., 10in. or 12in. Auto Stop. Baseplate 13 × 9½in. Height 5½in. Depth 11in. Price £7/15/6. post free.

Teletron Band III Converter

For London, Midland and Northern Transmissions
Suitable for all T.V. makes. T.R.F. or Superhet.
Ready wound coils, two EF90 valves, all components, punched chassis, circuit diagram, wiring plans. COMPLETE KIT for main operation. 200-250 v. A.C. £3/10/-.

AS ABOVE less POWER PACK. Requires 200 v. 20 mA. H.T. 6.3 v. .6 a. L.T.	£2/5/-
Mains Transformer to above Spec.	10/6
Min. Westinghouse Rect., ditto	5/6
Punched and drilled chassis	3/9
Larger chassis for Mains Model	6/-
Teletron Coilset with plans	15/-
BBC/ITA Crossover Unit	7/6
Variable Attenuator	6/-
Full plans and circuit details	6d

T.V. PRE-AMP. (McMICHAEL)
With amplify output of your Band 3 Converter. Tuneable Channels 1 to 5. Midget size. High gain triode model. B.V.A. Valve. Full instructions supplied. READY FOR USE. (H.T. 200V., L.T. 6.3V., .3 amp. required.) PRICE 95/- each. BRAND NEW, SPECIAL MAINS POWER PACK for above, 25/- extra.

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Long spindles. Guaranteed 1 year. All values 10,000 ohms to 2 Meg. No Sw. 3/-. S.P.Sw. 4/-. D.P.Sw. 4/9
EXT. SPKR. TYPE 3/-.

80 ohm CABLE Coaxial

Semi-air spaced Polythene insulated ½in. dia. Stranded core.
Losses cut 50% .. 9d. yd.
STANDARD ½in. Coaxial 9d. yd.

COAXIAL PLUGS 1/- DOUBLE SOCKET 1/6
SOCKETS TV AERIALS 1/- OUTLET BOXES 4/6
Band 3 Dipole indoor, 6/6. Band 3 Twin, 7/6 pr.
BALANCED TWIN FEEDER per yd. 6d. 80Ω or 300Ω.
TWIN SCREENED BALANCED FEEDER 1/- yd. 80 ohms.
TRIMMERS, Ceramic, 30, 50, 70 pf., 9d. 100 pf., 150 pf., 1/3. 250 pf., 1/6. 600 pf., 750 pf., 1/9.

ALUMINIUM CHASSIS. 18 s.w.g. Plain, undrilled, with 4 sides, riveted corners and lattice fixing holes, with 2in. sides. 7 × 4in., 4/6; 9 × 6in., 5/6; 11 × 7in., 6/9; 13 × 9in., 8/6; 14 × 11in., 10/6; 16 × 14in., 13/6 and 18 × 16 × 3in., 16/6.

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P.V.C. CONN. WIRE, 10 colours, single or stranded 24. yd.
tin. RADIO SCREWDRIVERS, 4½d. each.
NEON MAINS TESTER SCREWDRIVERS, 5/6.

VCR97 TESTED FULL PICTURE £2

MULTICORE SOLDER 60/40. 18 s.w.g., 2d., 16 s.w.g., 4d. yard, 1lb. 2/6.
SENTERCEL RECTIFIERS. E.H.T. TYPE FLY-BACK VOLTAGES. K3/25 7 kV., 4/3; K3/40 9 kV., 6/-; K3/45, 8.5 kV., 6/6; K3/50 4 kV., 7/3; K3/100 6 kV., 12/6; MAINS TYPE. RM1 125 v., 60 mA., 4/-; RM3, 100 mA., 4/9; RM3, 120 mA. 5/9; RM4, 250 v 275 mA., 16/-, G.E.C. Neon Osglim, S.R.C., 2/6.
COILS Wearite, "P" type, 3/- each. Osmor Midget "Q" type adj. dust core, 4/- each. All ranges.
TELETRON, L. & Med., T.R.F., with reaction. 2/6.
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F.M. TUNER COIL KIT. 22/6. H.F. coil, Aerial coil, Oscillator coil, two I.F. Transformers 10.7 Mc/s. Discriminator transformer and heater choke. With circuit and component list, using four 6AM6. Chassis and Dial, 19/6.

CONDENSERS. New stock. .001 mfd. 7 kV. T.C.C., 5/6. Ditto 50 kV., 9/6; 100 pf. to 500 pf. Mica, 6d.; Tubular 500 v., .001 to .01 mfd., 9d.; .05, .1, 1/-; .25 1/6; .5 1/9; .1/350 v., 9d.; .1/600 v. 1/3.

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4/450 v. .. 2/-	16+16/500v. 6/-	16+24/350 v. 4/6
8/450 v. .. 2/3	CAN TYPES	32+32/350v. 4/6
8/500 v. .. 2/9	Clips ..... 3d.	32+32/450v. 5/6
16/450 v. .. 3/6	16/450 v. 3/6	64+120/275v. 7/6
16/500 v. .. 4/-	32/350 v. .. 4/-	64+120/350v. 11/6
32/500 v. .. 5/6	64/350 v. .. 5/6	100+200/257v.
25/25 v. .. 1/9	100/275 v. 5/6	10/6
50/25 v. .. 1/9	50+50/350 v. 7/-	1,000+1,000/6 v.
50/50 v. .. 2/-	500/12 v. .. 3/-	8/6

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2D4	Equip.	E1148	EB91	ECH35
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5U4	6P41	3/6	(near)	ECH42
6AM6	EF92	3D6		EF41
6AT6		6H6M		EF80
6J7				EL41
6K8	7/6	7/6	7/6	EY80
6SL7	6SZ4	6V6G	EL32	KT2C
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SUPERHET COIL PACK 27/6 Miniature size 2¼ × 2¼ × 1¼in. High Q dust cored coils. 6 SHORT, MED., LONG GRAM switching with connection diagram and circuit.

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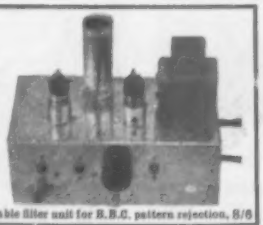

Kit of parts complete to build this most successful unit, comprising drilled chassis, valves, coils, res., cond., etc.; slightly modified version (Wireless World, May, 1954). £2/5/- post free. Send for blueprint and wiring diagram, 1/6 post free. Power Pack Components, including mains transf. and mot. resist., 20/- extra. Provision has been allowed on chassis for Band 1-Band 3 switching. Suitable for most types of T/V sets, T.R.F. or superhet.

B.B.C. BREAK-THROUGH FILTER, tunable filter unit for B.B.C. pattern rejection, 8/6

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3 WAVEBANDS:—L.W. 900m-2000m, M.W.200m-550m, S.W. 16m-50m. Chassis size 12½ × 8½ × 8½in. Attractive Gloss Dial 16 × 4½in. edge lit by 2 pilot lamps. Horizontal or Vertical Station Names and 4 control knobs, walnut or ivory to choice. 4 position W/C switch, L.M.S. and Gram. P.U. sockets. Modern circuitry, all coils adjustable, dust cored and only quality components used throughout. Delayed A.V.C. and neg. feedback. A.C. mains 200-250 v. Double wound transf. isolates chassis from mains. Aligned and calibrated ready for use.

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25/25 v., 50/12 v.	1/9	8 + 8/450 v.	4/6
50/50 v. 4/500 v.	2/-	8 + 16/450 v.	5/-
100/25 v.	2/-	8 + 16/500 v.	5/6
8/500 v.	2/6	16 + 16/275 v.	4/6
8 + 8/500 v.	4/6	16 + 16/450 v.	6/-
8 + 16/450 v.	5/-	16 + 32/350 v.	4/6
16/350 v.	3/-	32/350 v.	4/-
16/450 v.	3/6	32 + 32/275 v.	4/6
16 + 16/450 v.	5/6	50 + 50/350 v.	6/6
32/350 v.	4/-	50/350 v.	6/6
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32 + 32/350 v.	5/6	64 + 150/275 v.	11/6
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80 ohm CABLE — CO-AXIAL from 7/6.

SPECIAL.—Semi-air spaced polythene 5/- standard 1in. diam. Stranded core. Feeder 5/6 Inners cut 90°... 9d. yard.

Standard ½in., Grade A, 8d. yard.

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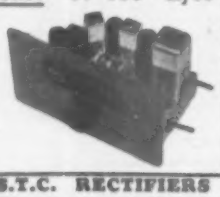
JASON F.M. TUNER UNIT 87-105 m/cs



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Tested and approved by "Radio Constructor," etc. Illustrated handbook with full details 2/-, post free.

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Wire ends. Silicone coated. 25 ohms—10,000 ohms, 5 w., 1/3. 10 w. 1/6. 15 w. 2/-.

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H.T. type. K3/25 2 Kv., 4/3; K3/40 3.5 Kv., 6/-; K3/45 3.6 kV., 6/6; K3/50 4 kV., 7/3; K3/100 8 kV., 12/6, etc.

Mains type. RM1 125 v. 60 mA., 4/-; RM2 125 v. 100 mA., 4/9; RM3 125 v. 120 mA., 5/9; RM4 250 v. 275 mA., 16/-.

RM4B type, 275 v., 275 mA., 17/6. L/T type F/W bridge 6-12 v. 1½ a., 9/9; 3 a., 15/6; 4 a., 18/6; 6 a., 21/6 each.

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T.V. knurled slotted knob type. 25 ohms to 50,000 ohms., 2/-; 50,000 ohms, 4/-; 50,000 ohms to 2 Megohms (carbon), 3/-.

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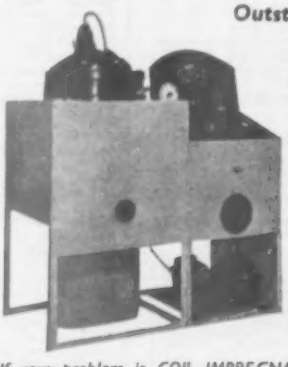

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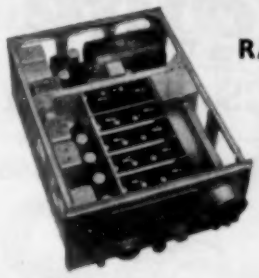

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A universal fitting plug which ensures effective cable and braiding clamping, and ensures quick and easy fitting. It is specifically designed for attachment to a wide range of cables. It is of robust construction and competitively priced. **Co-axial plug, Part No. 166** is available in large quantities and we shall be happy to quote for your requirements.

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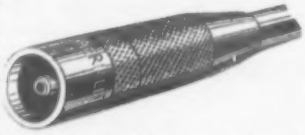
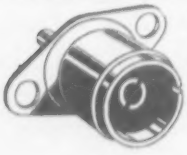


Ease of assembly is but one of the salient features of this **two-piece co-axial plug.** It is, like model 166, a well - designed plug which conforms to R.E.C.M.F. standards. Body finish is bright nickel plating and the pin is silvered. Competitively priced and available in quantities.

CO-AXIAL SOCKET Part No. 149



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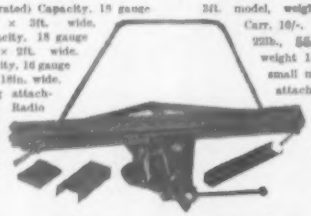

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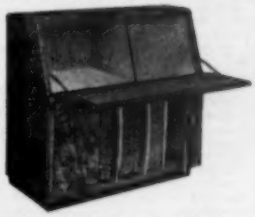

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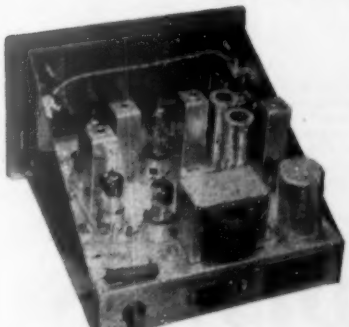

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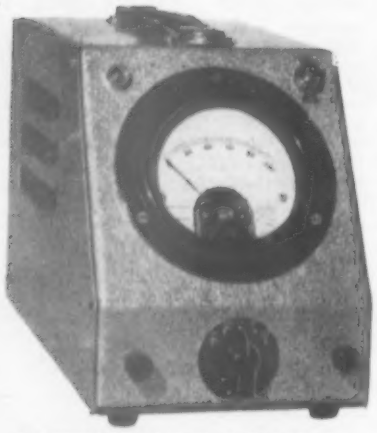

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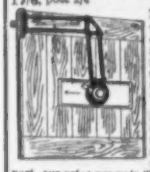

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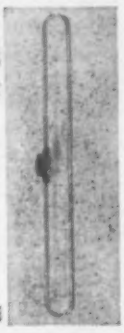

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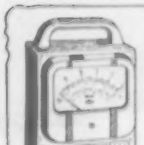

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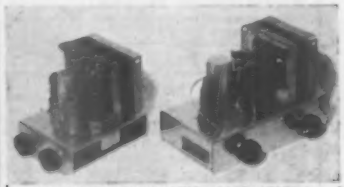

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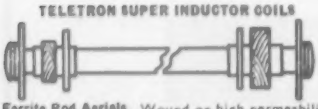

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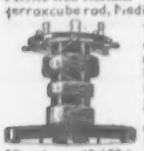

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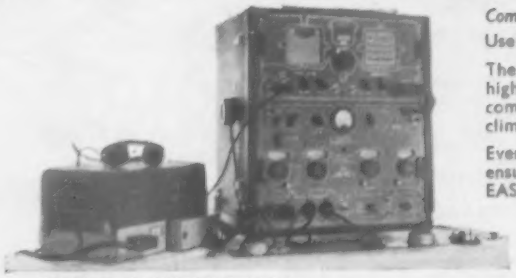

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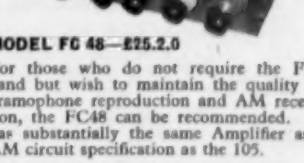

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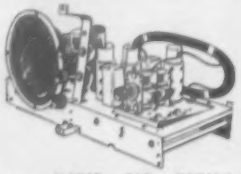

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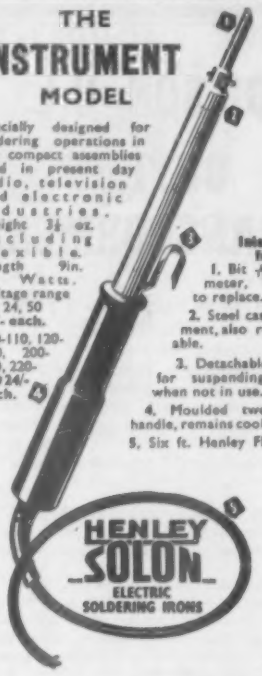

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ENGINEER required for development work on polystyrene film capacitors; position offers considerable scope for man with general experience in the capacitor industry particularly on the production side; own staff advised.—Write Box 2382. [6093

McMICHAEL RADIO, Ltd., Slough, Bucks, have vacancies from time to time for electronic engineers to be engaged on Government projects; those wishing to be considered are invited to write fully to the Chief Engineer, Equipment Division. [0196

TRAINEE Television Service Engineer required by London retail radio business of good standing; good opportunity for keen man with aptitude for this work; driving experience essential; state age and details of career.—Box 2761. [6137

ADVERTISERS (estab. '46) and well known, extending into the amplifier market, have profit-sharing and active proposition to put to man with knowledge in this branch and small capital; district S.W. London; reply in strictest confidence.—Box 1943. [6144

ERICSSON TELEPHONES, Ltd., Beeston, Nottingham, are planning a considerable expansion in the fields of acoustics and acoustic transducers, relays, hearing aids, electro-mechanical devices, etc., and invite applications from:
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ELECTRICAL Engineers.
MECHANICAL Engineers.
THESE posts, which offer considerable interest, are progressive and pensionable. In certain cases assistance with housing problems is available. Holiday commitments for this year will be honoured.
APPLY by letter to the Personnel Officer, quoting reference No. IG/4 and giving details of previous experience and salary required. [6143

THE MITCHAM WORKS, Ltd., have a number of vacancies for young draughtsmen to be trained as mechanical designers, these opportunities provide for interesting work, leading to recognition as qualified designers in the radio and television field.
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RADIO/TELEVISION service engineer for established Murphy dealer; seaside town; equipped modern test gear; only first-class engineer considered; good wages; permanent post, but no accommodation provided.—Gerry Bank St., Newquay. [6146

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SENIOR television development engineer with administrative experience required, capable of carrying out development projects with minimum supervision up to production stage; Kingston area.—Write, giving full personal details, stating salary required, Chief Engineer, Box 5942. [0125

ELECTRICAL measuring instrument repairers required for moving-coil, moving-iron and multi-range meters; expanding organisation with high rates, bonus scheme and excellent conditions in light modern factory.—Apply L. Glaser & Co., Ltd., 96-100, Aldersgate St., E.C.1. Mon. 6822. [6008

ELECTRONIC INSTRUMENTS, Ltd., Richmond, have a vacancy on their testing staff which offers the prospect of an interesting job in this rapidly expanding company.—Please write to Electronic Instruments, Ltd., Lower Mortlake Rd., Richmond, Surrey, or Tel. Ric. 5656. [6155

VACANCIES occur, through promotion to managerial posts of our present staff, for television field engineers in the following areas —Luton, Aylesbury and Bedford; existing holiday arrangements will be honoured.—Forward full particulars to F. J. R. Robinson Rentals, Ltd., 47, St. Peter's St., Bedford. [6149

SENIOR Engineer required by electronic component manufacturer to take charge of test gear development, factory standards and maintenance of electrical special purpose plant. Permanent position requiring man with initiative and sound theoretical background. State salary required. Box 2564. [6101

CHIEF Inspector (Electrical) required by electronic component manufacturers. A.I.D. experience essential, preferably on R.C.S.C. specifications. Position suitable for applicant at present senior inspector who wishes wider scope and better remuneration within a small organisation. Location London, E.11.—Write Box 2365. [6102

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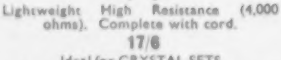

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ELECTRONIC Test Engineers are required by the General Electric Co., Ltd., Radio and Television Works, Spon St., Coventry; ex-Service radio and radar technicians and men with similar experience are particularly suitable for these posts; applicants should have an interest in one of the fields outlined below:—
(a) Testing of electronic equipment for Government contracts.
(b) Alignment, Test and Fault-finding on domestic T.V. receivers.
(c) Development, manufacture and maintenance of test equipment.
THESE positions offer good prospects of advancement. Those interested should write, quoting Ref. E.T. and giving details of career and experience, to the Personnel Manager at the above address. [6105

SENIOR and Junior Electrical and Mechanical Draughtsmen required for the Electronics Drawing Office of the British Thomson-Houston Co., Ltd., Blackbird Rd., Leicester.—Please apply in writing to Chief Draughtsman, Electronics Drawing Office, British Thomson-Houston Co., Ltd., Rugby, giving details of age, experience, etc. [5645

DESIGNER draughtsmen required by firm engaged in radio and electronic instrument work; experience in this field highly desirable; these are senior staff, pensionable appointments. Apply with details of experience and salary required to Personnel Officer, British Communications Corporation, Ltd., Exhibition Grounds, Wembley. [6114

AUSTRALIA (Sydney).—Television engineer with production experience required. Also experienced service engineer. Good salaries, bonuses, excellent prospects for right men. First class fares paid, accommodation guaranteed. Interview London. Replies, stating full particulars, treated with strictest confidence.—Box 2805. [6141

GOOD class radio and television dealers have opening for another experienced engineer who would help to retain their high reputation for service, top salary plus bonus, commencing date with respect holiday arrangements, permanency; excellent opportunity in expanding concern for loyal, qualified man.—Sievers, Marsh Road, Pinner 9285. [6135

RADIO engineers required to install and maintain two high power radio transmitting stations which will be isolated and climatic conditions rigorous with no local amenities; excellent salaries paid to men with necessary experience and right temperament.—Quote Ref. D/NF, Box WD.381, c/o 191, Gresham House, E.C.2. [6115

DEVELOPMENT Engineer required to work on tape recording applications; the successful applicant must have experience in developing tape recording machines from the mechanical, electrical and electronic points of view; this is a senior position and an appropriate salary will be paid.—Apply to Box A45/12, Strand House, London, W.C.2. [6055

ELECTRONIC engineers.—Large organization has a few vacancies for electronic engineers to train as project leaders taking charge of all aspects of contracts abroad; qualifications H.N.C. or equivalent; age group 26-32, must be single and willing to work anywhere abroad for periods up to two years; excellent salary.—Write Box WD.458, c/o 191, Gresham House, E.C.2 [6147

TECHNICIAN or senior technician required for psychological laboratory; must have workshop experience and be familiar with electronic apparatus; salary scale: Technician, £520—£630; senior technician, £620—£755.—Apply, giving details of age, qualifications and experience to Hon. Director, Medical Research Council Unit, Institute of Psychiatry, Maudsley Hospital, S.E.5. [6113

BRISTOL Mental Hospital Management Committee requires an Electronic Engineer to service maintain and construct electro-encephalographic and electro-physiological equipment at Barrow Hospital, near Bristol. Salary £625×£25—£800. Applications giving age, details of qualifications and experience, and names of two referees should be sent to Secretary, Bristol Mental Hospital, Fishponds, Bristol. [6129

GRADUATE electrical engineer.—Urgently required by International company at Oxford; unusual opportunity for man 27-35 with first-class qualifications for development work connected with TV circuitry; successful applicant must be able to spend month in United States this summer.—Applications with full details education, qualifications, experience, marital status and salary required to Box 2538. [6112

RADIO engineer required for Broadcasting Division, Social Development Department, Tanganyika, on contract for tour of 30-36 months in first instance. Salary scale (including inducement pay and present temporary allowance of 10% of salary) £1,005 rising to £1,494 a year. Gratuity at rate of 13½% of total substantive salary drawn. Outfit allowance £45. Free passages. Liberal leave on full salary. Candidates, preferably under 35, should have experience of high-power transmitting equipment and be able take charge of 20kW, 1·25kW and 250 watt R.C.A. transmitters at Broadcasting Station.—Write to the Crown Agents, 4, Millbank, London, S.W.1, stating age, name in block letters, full qualifications and experience and quote M2O/41312/WP. [6119

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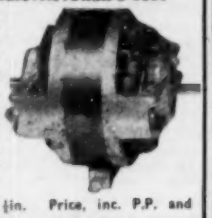

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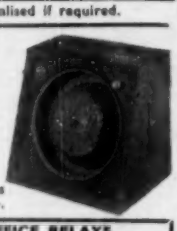

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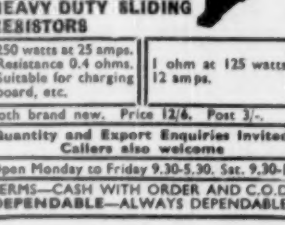

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RADIO technicians required by International Aeradio Ltd., for overseas service; permanent and pensionable positions; inclusive salary from £894 per annum to £1,375 per annum, tax free, according to marital status; free accommodation; kit allowance; free air fares; generous U.K. leave.—Qualified candidates, to whom replies only will be sent, please write, quoting RT to Personnel Officer, 40, Park St., W.1. [0262

RESIDENT Radio Station Engineer and Resident Assistant Engineer required for isolated site near Stirling; good theoretical knowledge and practical background of transmitting station operation required; specialised training will be given to selected applicants; salary £450-£750 p.a. depending on qualifications and experience plus free house and heat.—Reply, giving details of present position, experience and qualifications to Box WW.505, c/o 191, Gresham House, E.C.2. [6107

ENGINEER for printed circuits required for development of printed circuit processes, including electro-plating of various metals, also development of printed resistors; qualifications B.Sc., or equivalent and experience of electroplating and/or carbon resistors is desirable; superannuation scheme.—Write, giving full details of qualifications, experience, age and salary required to Personnel Manager, The Telegraph Condenser Co., Ltd., Wales Farm Rd., North Acton, W.3. [6094

TEST and Commissioning Engineer required by Elliott Bros. (London), Ltd., for interesting work on electronic instruments and systems. Applicants possessing O.N.C. or City and Guilds Intermediate preferred, but engineers with testing experience in this field are also invited to apply. The work is based on Lewisham, but occasional travelling is also involved.—Please write stating age, experience and qualifications to Personnel Officer, Century Works, Conington Rd., Lewisham, S.E.13. [6142

SKILLED radio mechanics and servicemen.—A large organization has vacancies for men who are prepared to travel and work anywhere in the world; periods abroad from 6 to 24 months; salary £75 per month plus all found; candidates must be single, medically fit and have a good knowledge of radio theory and practice; initial engagements one to three years with excellent opportunities for men with ability and right temperament to obtain permanencies.—Write Box WD.439, c/o 191, Gresham House, E.C.2. [6144

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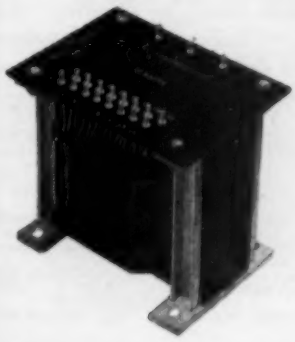
INSPECTOR of Workshops required for B. Broadcasting Department, Gold Coast Local Civil Service, for one tour of 18-24 months in first instance; consolidated salary scale £990 rising to £1,230 a year with gratuity at rate £100/£150 a year; outfit allowance £60, free passages, liberal leave on full salary; candidates must have up-to-date knowledge broadcasting equipment, should have at least ten years' experience workshops practice in radio, including five years in large broadcasting organisation, preferably B.B.C., or five years in large manufacturing firm in radio industry. Write to the Crown Agents, 4, Millbank, London, S.W.1, state age, name in block letters, full qualifications and experience and quote M3O/41090/WF. [6106



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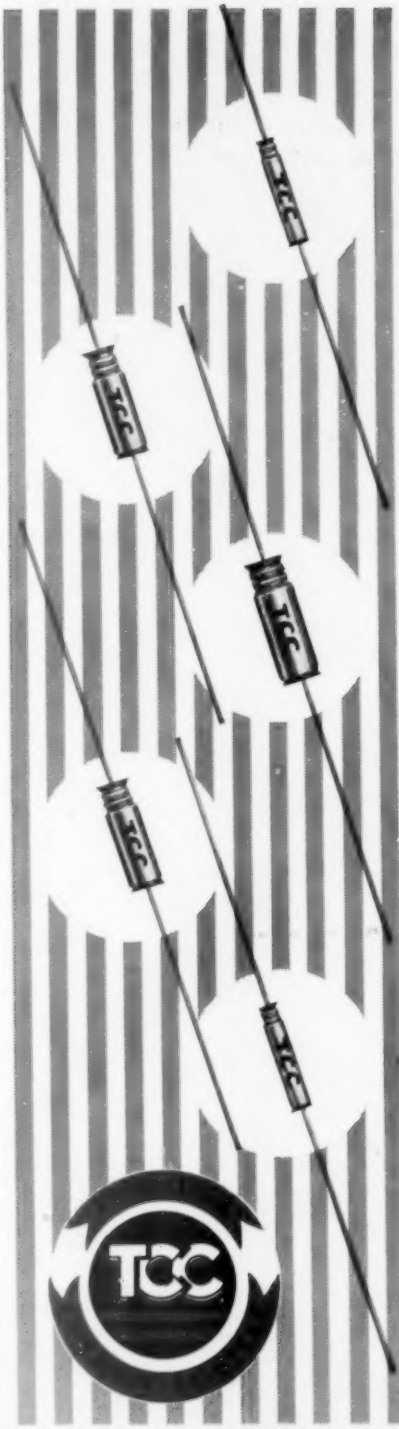

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for transistor circuitry

The introduction of transistors has created fresh impetus to the design of ancillary components of comparably small dimensions. For this purpose we have produced a range of Sub-Miniature Electrolytic Condensers, which we believe to be the smallest of their type ever made. These diminutive condensers are equally suitable for use in miniature walkie-talkie equipment, hearing aids, and similar assemblies where every component is scaled down to the absolute minimum physical size.

Terminations: these condensers are supplied with tinned copper wires, 1½" long.

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Tolerance of capacity —25% to +50%.

Capacity in μF.	Peak Working Volts	Dimensions in inches		T.C.C. Type Number
		Length	Diameter	
6	1·5	⅜"	⅛"	CE58
4	4	⅜"	⅛"	CE58AA
2	8	⅜"	⅛"	CE58A
1	12	⅜"	⅛"	CE58B
0·25	25	⅜"	⅛"	CE58C
6	3	9/16"	·18	CE68AA
10	3	9/16"	·18	CE68AA
1	25	9/16"	·18	CE68C
8	6	11/16"	·2	CE69A
4	12	11/16"	·2	CE69B
32	1·5	11/16"	¼"	CE67
8	15	11/16"	¼"	CE67B

T.C.C. Patent Nos. 578487, 578509, 587072.

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